Machinery and Apparatus for Manufacturing Chemists

James C. Shears

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FOR

MANUFACTURING CHEMISTS

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MANUFACTURING CHEMISTS

BY

JAMES C. SHEARS

Assoc. M. Inst. C.E.

LONDON

E. MARLBOROUGH & CO., 51, OLD BAILEY, E.C.

Having for many years been engaged in the manufacture of Pharmaceutical Laboratory Plant, and in the erection of some of the most modern factories for the production of crude and fine chemicals, food stuffs, soap, candles, etc., etc., and also of distilleries dealing with alcohol in every form, I venture to bring these notes before the various trades, in the hope that they may be of some assistance to those who may desire to establish factories requiring such plant as is herein described.

JAMES C. SHEARS.

London, *December*, 1895.

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MACHINERY AND APPARATUS

FOR MANUFACTURING CHEMISTS

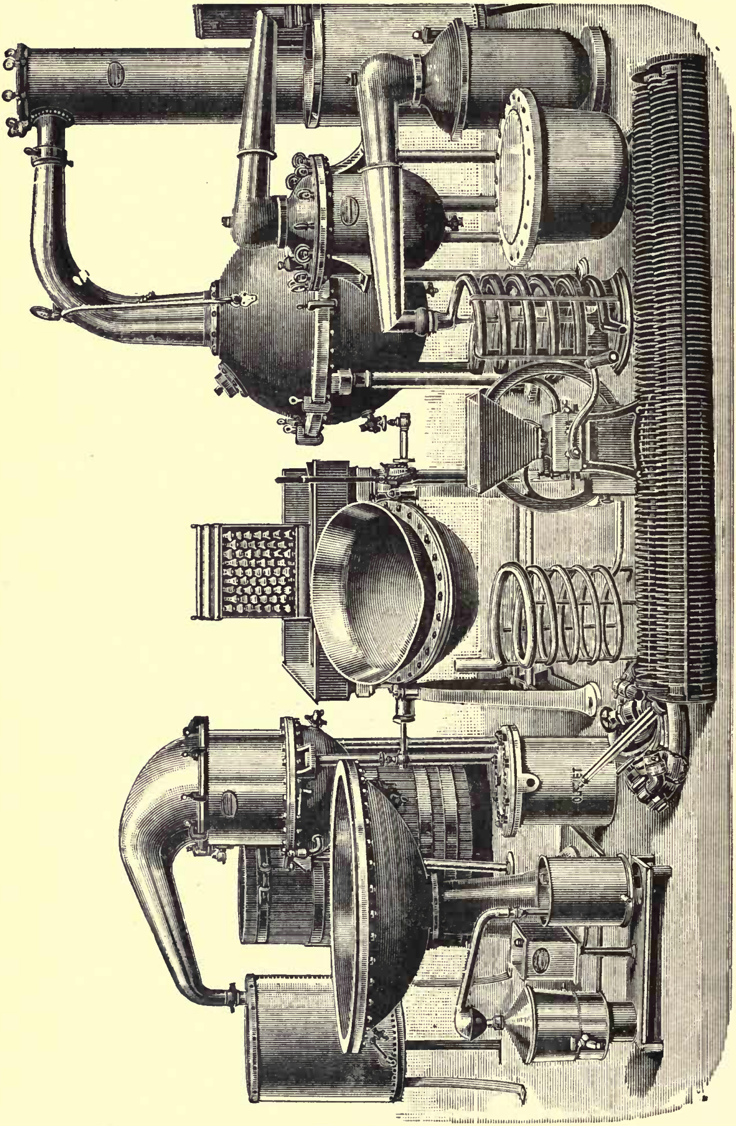
CHEMICAL FACTORIES.

An ideal chemical factory should be situated on the bank of a river or canal on the outskirts of a town, with separated buildings, not exceeding two storeys in height where possible, for each class of manufacture. They should be built in quadrangular form, with ample yard room, and should be connected, by a line of rails running into the yard, with an adjoining railway siding.

The floors and buildings should be built of fireproof material, and be capable of being washed all over, and should be commanded by a constant and powerful water supply for this purpose, to avoid risk of fire, as well as to supply the quantity required for manufacturing purposes.

The whole of the power should be supplied from one main engine, distributed over the various departments by shafting driven by gearing, belts, ropes, or chains. An exact duplicate engine should be kept in readiness for any breakdown, the engines being worked every alternate week, to keep them in thorough working order and condition.

Steam should be generated in Cornish or Lancashire boilers, with large steam-chests to allow of great



steam capacity, the flues from them being carried underground into one large shaft built directly from the ground—the boilers, like the engines, to be in duplicate, and worked every alternate week. Steam or hydraulic cranes should be fitted where necessary to each department.

A large weighbridge and office should be placed near the main entrance, and weighing machines in each department. All heavy machinery should be placed on the ground floors, which should be built of solid concrete covered with hard cement, sloping gradually to the drains. The doors should be amply large enough in each department to admit of any of the machines being got in or out whole, in case of necessity, and the cranes should be amply strong enough to lift the heaviest possible machinery or packages used.

STEAM BOILERS.

An unit of heat is the standard measure for the amount of heat absorbed or evolved during any operation, and is the amount of heat required to raise the temperature of a pound of water 1° F. to 32° F.

A cubic foot of water at 60° F. evaporated to steam at any pressure is equal to one nominal horse-power, 70,000 units of heat, and about two-thirds of this quantity may be reckoned as equal to one net indicated horse-power.

The unit of power used as a standard is the power necessary to raise 1 lb. avoirdupois 1 ft. high per minute.

A horse-power being the power necessary to raise 33,000 lb. 1 ft. high per minute, or 33,000 foot pounds

per minute; but in calculating the power required for any work allowance must be made for friction.

The boilers most used for chemical works are of the vertical, Cornish, or Lancashire type.

Vertical boilers, both with vertical or cross-tubes, cannot be recommended, because they rarely have much steam capacity. They certainly have the advantage of occupying small space, but they require constant attention as to stoking, as they make and lose their steam very quickly.

Cornish (one-flued horizontal boilers) or Lancashire (two-flued horizontal boilers), with large steam-chests to form steam reservoirs, are most suitable for chemical work, having all the fittings fixed on the steam-chest, insuring dry steam and obviating priming.

Steam boilers up to 10 h.p. should have 18 ft. per h.p. effective heating surface; 10 h.p., 14 sq. ft.; 20 h.p., 12 sq. ft.; and 50 h.p., about 11 sq. ft., with 1 sq. ft. of grate surface for small boilers, and $\frac{3}{4}$ ft. for large above 20 h.p.

The average quantity of coal consumed per square foot of grate area in ordinary boilers is from 12–14 lb. per hour.

Comparative Value of Fuels.

Welsh Coal	1
Newcastle Coal	0·885
Derby and Yorkshire Coal	0·837
Lancashire Coal	·877
Scotch	·851
Irish Anthracite	1·088
French average	0·884
Lignites average	·736
Welldrew Peat	·500
Coke average	·995
Oak	·500
Pine	·276

All steam boilers should be tested by hydraulic pressure to double their working pressure, and be thoroughly inspected at stated intervals, and should be blown out at each week end, if possible.

All fittings should be connected to the boilers by flanges, and all the cocks should be safe bottom and gland cocks.

There should be two sets of water-gauges on each boiler, and two safety valves, one either dead weight or spring type, and the other of the lever type.

An anti-priming pipe should be attached to the steam stop-valve, and an internal distributing pipe to the feed-valve.

Each boiler should have two separate means of water supply in case of accident: one to be some form of feed pump, and the other some method of steam feed injection.

Cornish, or single-flued boilers, and also Lancashire two-flued boilers, are usually made from 3 ft. to 6 ft. diameter, and Lancashire, or double-flued boilers, from 5 ft. 6 in. to 8 ft. diameter. The following tables give approximate dimensions for both types:—

CORNISH BOILERS, ONE FLUE.

Suitable for h.p.	Diameter.	Length.	Flue diameter.	Plates for 60 lb. working pressure.		
				Ends.	Shell.	Flues.
	ft. in.	ft.	ft. in.	in.	in.	in.
15	3 9	24	2 3	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
18	4 0	26	2 6	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
27	4 6	28	2 7½	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
33	4 9	28	2 9	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
42	5 0	30	3 0	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
50	5 6	30	3 3	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{1}{2}$

LANCASHIRE BOILERS, TWO FLUES.

Suitable for h.p.	Diameter.	Length.	Flue diameter.	Plates for 60 lb. working pressure.		
				Ends.	Shell.	Flues.
	ft. in.	ft.	ft. in.	in.	in.	in.
65	6 0	24	2 3	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
76	6 6	26	2 6	$\frac{9}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
85	6 9	28	2 $7\frac{1}{2}$	$\frac{5}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
90	7 0	28	2 9	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
104	7 6	30	3 0	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{2}$
112	8 0	30	3 3	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{1}{2}$

Diameter of flue = diameter of shell × 4.

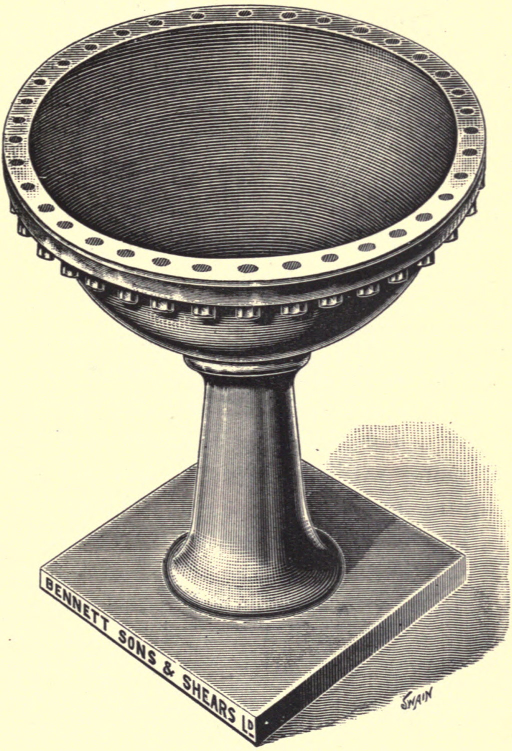
The i.h.p. is rated on the assumption of 7 sq. ft. of heating surface for each i.h.p.; in practice, the larger boilers will supply steam for 2 or 3 times the i.h.p. given in the tables.

For example, a Lancashire boiler 28 ft. × 7 ft. will supply steam for an engine from 150 to 200 i.h.p., and a boiler 30 ft. × 8 ft. is capable of supplying steam for an engine of 350 to 400 i.h.p.

Boilers should incline about 1 in. in 20 ft. to empty easily. Firebars should incline about $\frac{1}{2}$ in. to $\frac{3}{4}$ in. per foot of length.

EVAPORATING PANS.

Copper steam-jacketted evaporating pans should be shallow, in the proportion of about $3\frac{1}{2}$ to 1 as their diameter is to their depth. They are best fitted in cast-iron steam jackets on pedestals, and jointed at the rim with flush wrought-iron jointing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SWAIN

ring, or into the copper brim only. The copper should not be less than $\frac{3}{16}$ in. thick for 20-gallon capacity, and thicker for larger sizes in proportion.

The following will be found useful sizes and proportions :—

20	gallons	capacity,	34	in. diameter	at	throat	× $10\frac{1}{2}$	in. deep.
25	,,	,,	36	,,	,,	,,	× 11	,, ,,
30	,,	,,	40	,,	,,	,,	× 12	,, ,,
35	,,	,,	42	,,	,,	,,	× 13	,, ,,
40	,,	,,	44	,,	,,	,,	× 14	,, ,,
50	,,	,,	46	,,	,,	,,	× 15	,, ,,

The copper pans can be silver plated, tinned, or slabbed with solid block tin, as desired.

To assist rapid evaporation in these pans, what is known as the towel evaporator can be applied to them: it is merely an endless towel carried on top and bottom rollers, the top roller having its carriages fastened to a ceiling overhead, and being driven slowly by a belt from an adjacent shaft, and the bottom being made to dip into the pan revolving in hanging bearings attached temporarily to its brim. The towel in its travel carries with it continuously a quantity of the liquid in a film, which gives forth its vapour rapidly in the atmosphere.

When the goods are sufficiently concentrated, the towel can be washed out, the washings being added to the bulk, to make up the desired quantity.

COPPER STEAM PANS.

Copper steam-jacketed boiling pans, as distinct from evaporating pans, should be semicircular in shape, with light courses added if necessary. They

should be jointed in cast-iron steam jackets, with wrought-iron jointing bands and cupheaded countersunk bolts and nuts, and be mounted, the small sizes on pedestals and the larger on cast-iron columns. Small pans of copper should not be less than $\frac{3}{16}$ in. thick and larger sizes thicker in proportion.

The following will be found useful sizes and proportions :—

20	gallons	capacity,	29	in.	diameter	at	throat,	14½	in.	deep.
30	"	"	32	"	"	"	"	16	"	"
40	"	"	36	"	"	"	"	18	"	"
50	"	"	38	"	"	"	"	19	"	"
60	"	"	40	"	"	"	"	20	"	"
80	"	"	44	"	"	"	"	22	"	"
100	"	"	48	"	"	"	"	24	"	"

Every 10 feet of heating surface in a pan may be reckoned to require one horse-power of steam per hour = 1 cubic foot of water evaporated to steam per hour.

ENAMELLED IRON PANS.

Enamelled iron pans are largely used in chemical works for containing and evaporating goods which are required to be free from metallic influence.

Wrought-iron enamelled pans are far superior to cast-iron, as the enamel adheres to them better; but on account of the difficulty and expense of making them in any size in one piece, cast-iron is more generally used; but however good the enamel may be, it soon cracks and comes away from the metal, even when it is carried over a projecting rim standing above the throat of the pan, which, however, is a

safeguard to some extent. There has always been a difficulty in making pans and vessels with holes cast in them, or which require to be jointed together, or have other parts jointed to them, on account of the enamel breaking away from the edges of the holes in the process of jointing. A cast-iron enamelled vacuum pan is a great desideratum; but as yet a satisfactory one has not been produced.

Receivers are made with flat or curved rims, and measure about the same in depth as in diameter.

5	-gallon	receivers	measure	14	in.	diameter	inside	dimensions.
10	,,	,,	,,	18	,,	,,	,,	,,
20	,,	,,	,,	24	,,	,,	,,	,,
30	,,	,,	,,	26	,,	,,	,,	,,
40	,,	,,	,,	29	,,	,,	,,	,,
50	,,	,,	,,	32	,,	,,	,,	,,
60	,,	,,	,,	36	,,	,,	,,	,,
70	,,	,,	,,	38	,,	,,	,,	,,
80	,,	,,	,,	40	,,	,,	,,	,,
90	,,	,,	,,	42	,,	,,	,,	,,
100	,,	,,	,,	43	,,	,,	,,	,,

Cast-iron enamelled steam-jacketed pans are made in both shallow and deep forms, but usually of the following proportions:—

5	gallons	capacity,	16½	in.	diam.	× 8	in.	deep	inside	dimens.
10	,,	,,	23	,,	,,	×10	,,	,,	,,	,,
20	,,	,,	26½	,,	,,	×15	,,	,,	,,	,,
30	,,	,,	29	,,	,,	×16½	,,	,,	,,	,,
50	,,	,,	36	,,	,,	×21	,,	,,	,,	,,
60	,,	,,	40	,,	,,	×23	,,	,,	,,	,,
100	,,	,,	46	,,	,,	×26	,,	,,	,,	,,

PEWTER STEAM PANS.

Pewter steam evaporating pans are costly articles to purchase, but repay their cost in a short time, and are much more satisfactory for evaporating green extracts, etc., than copper pans lined or slabbed with pure tin or enamelled iron pans, neither of which last very long.

Pewter, such as these pans are made of, should be practically pure English block tin, only tempered sufficiently to enable the metal to be worked, and free from lead and antimony. Steam at 10 lbs. pressure per square inch is quite the limit of heat that should be applied to them, and no steam jet should be allowed to play directly on to the pewter.

Steam should be let into the jacket at two or more places under guard plates, so as to evenly divide the expansion over the whole area of the pan, and special care should be taken to free the jacket from air, which expands enormously as it becomes heated, and tends to lift the throat of the pan. The pans are made in sections shaped and burnt together with hot irons, with their own metal freed from flaws, and then hammered and flanged by hand, and planished hard on bright anvil tools. No pan should be made less than $\frac{3}{4}$ in. thick. They usually vary in size from 2 ft. to 4 ft. diameter at throat × 6 in. to 18 in. deep. They can always be considered good property, and when sagged or mis-shaped, or cracked by heat and wear, can be melted down and revivified with a proportion of new metal, and worked up again to their original shape at the cost of very little more than the labour employed.

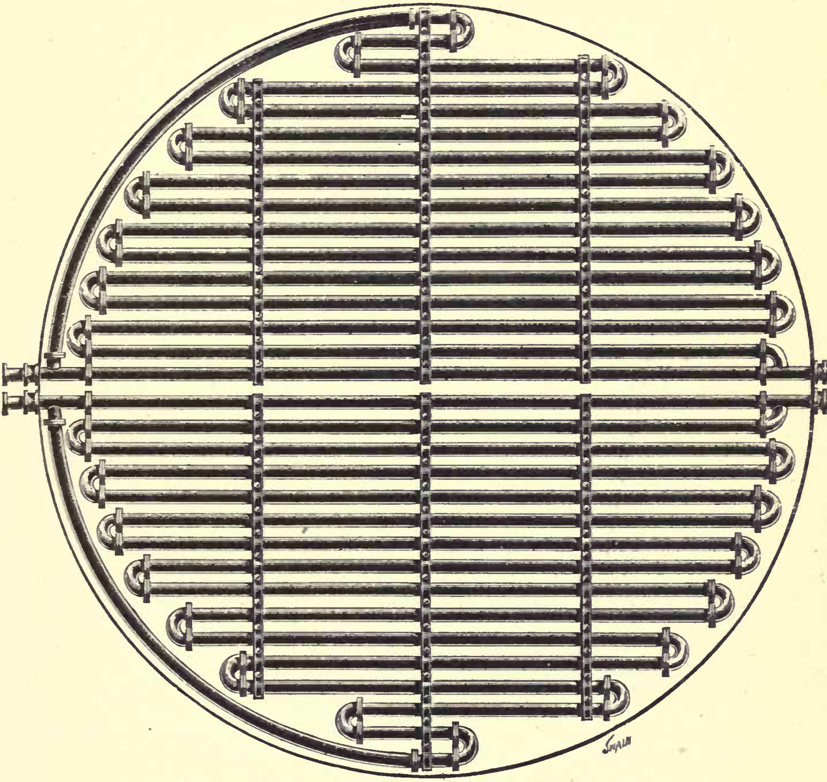
The manufacture of fine pewter is somewhat of a lost art, and very few persons have a thorough knowledge of it.

TILTING PANS.

Steam-jacketed tilting pans are very useful appliances, but are in much more general use for jam making and fruit preserving than for pharmaceutical purposes. Their greatest utility is for melting substances for subdivision into jars, and for rapidly evaporating small quantities of valuable fluid extracts, which can be emptied out, by tilting, to the last drop, thus insuring no such loss as occurs where baling out is necessary. They are usually of copper, from 5 to 40 gallons content, with a copper light course, having a pouring lip in the front. They can be fitted in cast-iron or copper steam jackets on trunnions, with stuffing boxes for the admission of steam and the eduction of condensed water, the trunnions being mounted on, and working in, bearings on columns or frames, and the pans having a tilting lever attached, which can be kept in any desired position by a pin passing through a quadrant attached to one of the frames. When the pans are of large size and heavy, worm and worm-wheel gear is substituted for the tilting lever.

STEAM BOILING COILS.

Liquids can be very efficiently boiled by means of steam enclosed in coils of piping, or by blowing the



DOUBLE WING COIL FOR BOILING ROUND

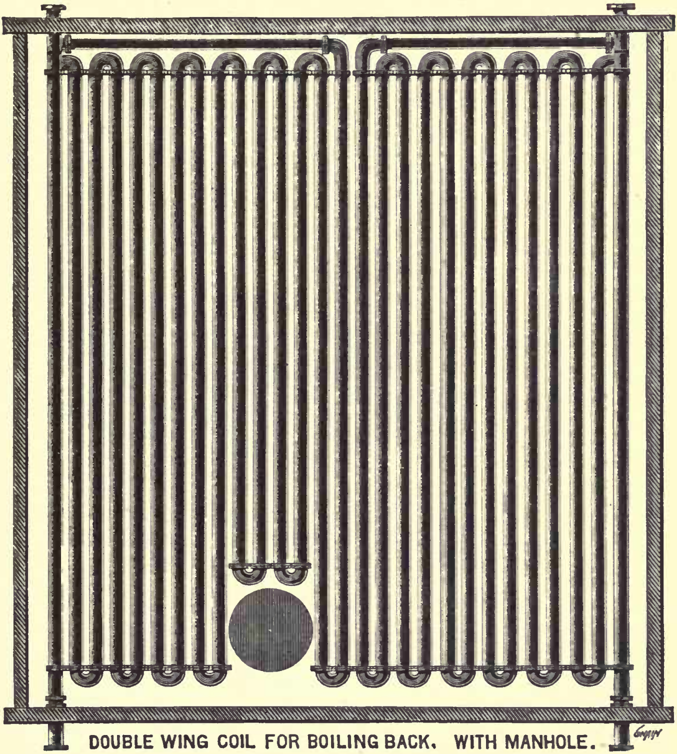
steam by a pipe or silent boiling nozzle direct into the liquid to be heated.

Steam coils are best formed of copper pipe, on account of its great conductivity. They should always be placed right on the bottom of the vessel containing the liquid to be boiled, and be formed in such a manner that the steam has sufficient length of travel or circulation before becoming condensed to enable it efficiently to impart its heat to the liquid. Each steam coil should be connected to a steam trap, to enable the water to be automatically and continuously discharged, so that the coil is kept free from water, and there is consequently no heat lost by too rapid condensation, or by the coil becoming water-logged.

In calculating the surface required in any coil to boil a given quantity of liquid in a given time, the pressure and consequent temperature of the steam must be taken into consideration, and the requisite number of units of heat per square foot of surface per hour allowed for, 1° F. difference of internal and external temperature. Roughly, it is usual to allow 4½ to 6 ft. of heating surface in a steam coil for every 100 gallons in the capacity of the vessel containing the liquid to be boiled.

Every 10 ft. of heating surface in the coil may be reckoned to require 1 h.p. of steam per hour, 1 cubic foot of water evaporated to steam.

When water is heated by blowing in direct steam, the volume is increased by the steam becoming condensed that is used in raising the water from its initial temperature to boiling point. The volume is thus usually increased about one-fifth. This is certainly the most economical method of heating

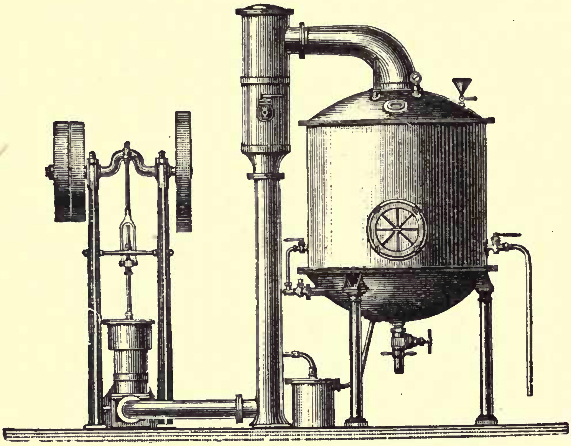


DOUBLE WING COIL FOR BOILING BACK. WITH MANHOLE.

water by steam, as the whole of the heat in the steam is imparted to the water.

VACUUM PANS.

The vacuum pan was invented and patented by Mr. E. C. Howard in 1812, and may be described as a closed vessel in connection with an air-pump for the evaporation of liquids at low temperatures. For ordinary purposes the atmospheric pressure may be taken at 15 lbs. per square inch, or equal



to 30 inches of mercury, and at this pressure the boiling point of liquids is constant, but is liable to be affected by change of circumstances, which may arise from various causes, such as the amount of pressure exerted upon the surface of the liquid, the density of the liquid, the substances held in

solution in the liquid, *i.e.* its hygroscopic nature, the nature of the vessel containing the liquid, and the depth of the liquid mass. Boiling water is nearly always of one temperature, because it is exposed to a tolerably uniform atmospheric pressure; but could this pressure be removed the boiling would take place at a considerably lower temperature. Hence the boiling point of a liquid varies with the pressure over its surface; the greater the pressure the higher the temperature at which it boils, and *vice versâ.* But boiling or ebullition is not necessarily produced by the application of heat, for by simply removing the pressure a liquid previously in a quiescent state may be made to boil. For example: in a close vessel containing a quantity of warm water placed in communication with an air-pump, as exhaustion proceeds, and gradually withdraws the pressure from the surface of the water, the water will commence to boil at a certain point of rarefaction; but supposing the air pump to stop working, the boiling would soon cease, and for this reason: that the vapour gradually accumulates, and having no means of escape, at length exerts a pressure over the water equal to that of the external atmosphere, and hence the boiling will cease. It will thus be seen that were it not for the pressure of the atmosphere it would be difficult, or perhaps impossible, to procure hot water.

Boiling water, it is true, might at all times be obtained with the greatest facility, but the water in this case would not be hot. That a liquid should boil and not be hot seems to imply a contradiction; but it must be borne in mind that the term boiling is simply the rapid formation of vapour

at all points of a liquid without reference to the degree of temperature.

Boiling can take place in a vacuum pan as low as at 80° Fahr., with a perfect vacuum. In a vacuum pan each foot of heating surface will evaporate about twice as much water per hour as in an open pan. Vacuum pans are made in copper and in cast and wrought-iron, with steam jackets, and with and without steam coils, and are used principally for boiling and granulating sugars, concentrating milk, worts, and all products and extracts which require to be evaporated, concentrated, dried, or distilled at low temperatures.

In an ordinary vacuum pan with jet condenser the vapour is condensed by, and passes through, a wet air-pump with the condensing water. An efficient wet vacuum pump for exhausting a vacuum pan should have a capacity of 1,900 circular inches of piston displacement per minute per foot of heating surface in the pan. The amount of water required for use in the condenser of a vacuum pan varies with the form of condenser and that of the spraying apparatus. The very best forms require about ten to twelve gallons of water per hour per foot of heating surface in the pan, and inferior forms sixteen to eighteen gallons.

The best and most economical results are obtained in a Torricellian condenser, through which a much larger amount of water is allowed to fall than is necessary for merely condensing the vapour from the pan. This water being collected at the base in the tank and pumped up again, so as to be used over and over again, and in first cost the necessary plant is expensive. In a vacuum pan fitted with a

Torricellian condenser, the vapour is condensed by injection of water which falls 34 ft., and runs to waste—the air only being withdrawn at the same time from the top of the condenser by a dry vacuum pump.

In a vacuum still the vapour is condensed in a closed tubular condenser surrounded by water, and passes into one or more receivers as distillate, the air being withdrawn from the top of the receiver by a dry vacuum pump, and the distillate being preserved or allowed to run to waste as desired.

Vacuum pans vary in size from a few inches in diameter to 24 ft. in diameter, and from a capacity of 1 gallon to 10,000 gallons.

To dry glutinous substances in vacuo, or to dry substances containing crystallizable matter, such as malt extract or patent foods, to a friable powder a special form of vacuum pan is required, having a flat bottom with deep sides and dome, the bottom and sides being steam-jacketed all over, and being polished inside, and fitted with a close-fitting revolving rousing apparatus, with knife edges, sweeping the whole of the surface so close as to prevent a single grain adhering and getting caked on to the surface—the rouser being fitted with cross-blades to break up any lumps and prevent massing or clogging. Any desired temperature can be used in these pans; and as there is very little moisture in the goods to vaporize, they only require connecting to an ordinary form of condenser, and either a dry or wet vacuum pump, in which a good vacuum can be maintained. It is possible to boil goods in vacuo at 500° F. by using superheated steam, and to boil sugar for manufacturing toffee

or hard crack from a mixture of cane sugar and glucose with ordinary high-pressure steam at temperatures up to 350° F., without any possibility of granulation setting in. Pans for this purpose have a very large amount of both steam jacket and coil surface, with a condenser pipe of a small throttled area, and produce goods of a much more regular consistency and more rapidly than they can be produced at the same temperatures in open sugar-boiling pans over an open fire. This system also obviates the risk of fire, and is much more cleanly than the use of fire heat.

The most economical results in evaporation in vacuo can be obtained by the multiple effect apparatus which is now in common use, and which is composed of a series of vessels, each having a steam chamber from which the vapour rising from evaporation in the first vessel passes away as steam to heat the second, and the vapour or steam produced in the second heats the third, and so on.

These apparatus are known as double, triple, and quadruple effect, and consist of a series of vessels having tubular steam chambers arranged vertically or horizontally, in which a vacuum is formed and graduated, so that the liquid to be treated is boiled at a constantly low temperature in proportion to its degree of concentration. Exhaust steam from engines and live steam, only when necessary, are generally used in the first vessel; hence the economy in working, as it will evaporate and condense a quantity of water in each vessel nearly equivalent to its own weight.

There are various patented forms of multiple effect evaporators, but perhaps the most successful

is that known as the Yaryan, an American invention. This invention relates to an improved evaporating and distilling apparatus operated in multiple effects, in which the evaporation takes place while the liquid is flowing through heated coils of pipe or conduits, and in which the vapour is separated from the liquid in a chamber at the discharge end of the coils, and is conducted to the heating cylinder surrounding the evaporating coils of the next effect from the first to the last effect.

STIRRERS.

Mechanical stirrers applied to evaporating pans add very much to the efficiency of the pans, and save an immense amount of labour. There are, however, many practised laboratory hands who declare that there is no better system than hand-stirring with spatulas.

The simplest and best form of mechanical stirrer consists of a short shaft with socketed end, into which the stirrer blade is fastened by a set screw, or with a plain end with two set screws which fasten the stirrer blades (preferably made of hard wood) at any desired angle, the blades having long slotted holes for the set screws to make them adjustable.

To the upper end of the shaft a mitre wheel is keyed, driven by another mitre wheel keyed on a short lay shaft, having strap or gut pulleys on to other end. Both the vertical shaft and the lay shaft are fitted in bearings contained in a cast-iron frame bracket, which can be bolted to a wall as a cantilever, or to a beam fixed over the centre of the

pan containing the goods to be stirred, the bearings having loose swivel caps which allow the shaft to be withdrawn immediately when desired.

For stirring or blending in deep vessels the vertical shaft should be made hollow, and have another one passing through it and projecting below it, each being fitted with a mitre wheel driven by the mitre wheel on the lay shaft in opposite directions, so that the blades on these shafts pass each other and churn up the goods through which they pass. These can be very easily and cheaply constructed of ordinary wrought-iron steam tubing, with a solid toe-step working in a bearing attached to the top of a vessel.

BOILING FOUNTAINS.

This apparatus consists of a copper inverted funnel, having holes at its base, with a vertical pipe and hood, and can be used in any boiling vessel or evaporating pan to enable a large quantity of liquid to be heated in the vessel without boiling over.

The fountain, when placed in a vessel or pan, should practically cover the heating surface, and will cause an upward current of the boiling liquor to enter the cone through the holes, rise through the vertical pipe, strike the hood at top, and return to the pan, thus dissipating great heat in vapour and preventing boiling over.

Care should be taken to ensure the steam inlet or inlets into the jacket of the pan in which it is used being directly underneath the cone. The vertical pipe is preferably made telescopic, so that it can be regulated at will to the force of the upward current.

This simple apparatus will save a considerable

quantity of fuel, and efficiently aerate the boiling liquor in which it is placed.

DISTILLATION.

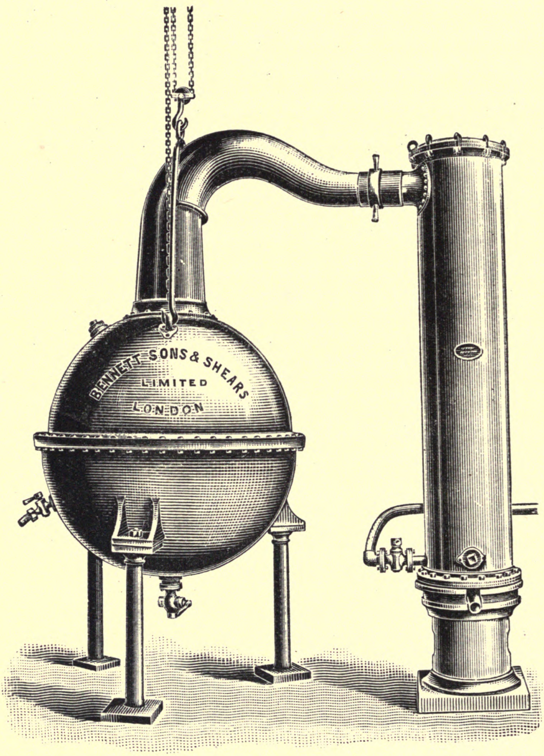
A still was formerly called in English the stillatory, from the Latin word *stilla*, a drop, *stillare*, to drop; and retort is from the Latin *retortas*, past participle of *retorquere*, to twist back.

Distillation is the evaporation of a liquid in a close vessel to vapour, the vapour thus evaporated being conducted into a refrigerator, where it is condensed and liquefied again.

The boiling points of liquids differ considerably. Water boils at 212° F., and alcohol at 173° F., so that in a mixture of those liquids the alcohol vaporizes first and separates itself from the water; it, however, does not do so entirely, but carries over with it a quantity of water with which it becomes entangled, and requires to be re-distilled or rectified to become pure.

Boiling points of liquids at atmospheric pressure are as follows:—

	Sp. gr.	F.
Sulph. ether	·7365	100°
Alcohol	·813	173°
Muriatic acid	1·047	222°
Nitric acid	1·16	220°
	1·3	240°
Sulphuric acid	1·85	620°
Oil of turpentine		316°
Naphtha		306°
Sulphur		570°
Linseed oil		600°
Mercury		662°
Glycerine		554°
Water		212°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Stills for various purposes consequently differ very much in form, but can be divided into two classes —the first being for ordinary distillation, and the second for continuous distillation.

In the first case the still is charged with a given quantity, heat applied, and vaporization and condensation continued until the charge is entirely evaporated or exhausted of alcohol. In the second case the charge runs continuously into the still during the process of distillation, assisting in its course to condense the spirituous vapour arising, and in its turn giving forth vapour evolved by the heat absorbed by coming in contact with the heated vapours rising from the body of the apparatus.

Spirit is distilled from fermented wash made by the infusion of malted and unmalted grain, sugar, molasses, wines, wine lees, fruit, flowers and seeds and aromatic plants.

Destructive distillation is the decomposition of a substance in a close vessel in such a manner as to obtain liquid products.

By a product is meant a body not originally present in the substance distilled. A body merely extracted without change by distillation is termed an educt. Manufactured ozokerite consists in part of educts from the native mineral; but this is a singular case in the industry of destructive distillation.

The apparatus employed in destructive distillation consists essentially of a retort followed by a condenser and a receiver. The substance to be operated on is placed inside the retort, to which heat is applied. The volatile products pass over and are condensed in long straight or vertical tubes, which

are kept more or less cooled. The average contraction from heated vapour to liquid may be taken at about 1,000 to 1. The retorts or stills are of various forms, and either horizontal or vertical, and are made of glass, iron, clay or brick. Heat is applied directly either to sides or bottom, or both, and superheated steam alone may be driven in at one end. Steam of varied temperature and direct heat are sometimes used together.

The nature of the product depends mostly on the composition of the substance heated and the degree of heat applied.

The retort was, doubtless, originally derived from the clay bottle, which in its turn was modelled on an animal skin or vegetable seed case.

In the sixteenth and seventeenth centuries destructive distillation came to be the principal work in chemical laboratories. Most animal substances, sometimes the whole body, such as that of the viper, also plants, were examined or analysed; but seldom any detailed investigation was made of the products.

ESSENTIAL OIL DISTILLATION.

Essential oils exist in most aromatic plants in their different organs, more particularly in their leaves, flowers or fruits, and most give their largest yield when dealt with in a fresh state. Most of them can be extracted by distillation in stills worked by fire or steam, preferably the latter, fitted with a perforated false bottom to prevent the matter adhering to the bottom of the still. The distillate must be

caught in a separator, in which the oil is separated from the water.

Various forms of stills can be used for this purpose. The matter should be placed in the still with water in which it has been macerated. Salt is sometimes added to retard the point of boiling to about 229° F., particularly when the oil is heavy, as it separates easier if distilled above 212° F., but it sometimes injures the distillate.

When distilling crystallizable oils, such as aniseed, caraway, peppermint, fennel or roses, care should be taken to keep the condenser rather warm—about 115° F.—and in some cases the condenser should command the still, so that the watery portion of the distillate, or mother liquor, can be continuously passed back from the separator to the still until it is exhausted of oil, when it will run out in a limpid form and loses its milky appearance.

Among the number of essential oils that are distilled may be mentioned bay, camomile, cloves, cubebs, dill, eucalyptus, geranium, lavender, neroly-bigarade, orange-flower water, otto of roses, oil of orris, pimento, peppermint, rosemary, thyme, spike-lavender. Essential oils heavier than water at 15° C. = 59° F. are cassia, 1·060 sp. gr.; cinnamon, 1·030; clove, 1·050; and those lighter than water, bay, ·990; bergamot, ·885; caraway, ·925; camomile, ·910; citronella, ·887; copaiba, ·900; cubeb, ·925; dill, ·914; pine, ·870; and rosemary, ·900.

ALCOHOL STILLS.

What the manufacturing chemist knows as an alcohol still is any still in which he can recover spirit from marcs or rectify any spirit which has become dirty and weakened by use in percolation or washing processes. In mixing alcohol with water it must be remembered that equal quantities of each contract in bulk nearly 4 per cent., *i.e.* 100 c.c. of alcohol and 100 c.c. of water contract to 192·8 c.c. when mixed.

Perhaps the most useful pattern is the French one, consisting of a copper steam jacketed still, flanged at top and surmounted by a turk's cap still-head connected to the worm by a tapering vapour-conducting pipe, bent to a large radius, and consequently standing some considerable height above the still, thus ensuring clean spirit; the worm usually has a vapour globe at top, which effects a steady flow of distillate and is contained in an ordinary copper or galvanized iron worm tank.

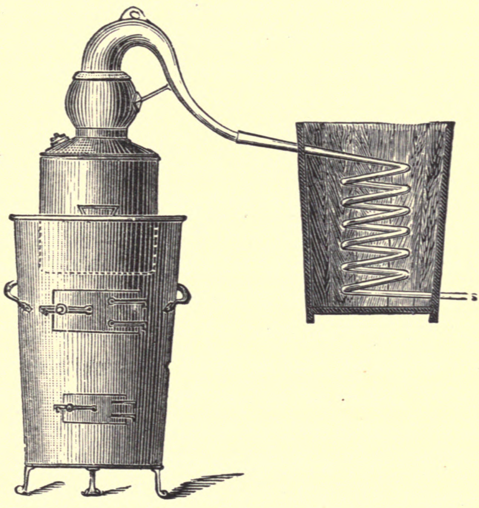
The Excise will not permit any apparatus to be used for recovering methylated spirit from marcs, etc., which rectifies the spirit so as to increase its strength.

ALMOND OIL STILLS.

The best form of still for extracting almond oil is made of copper, of elliptical form, fitted in a steam jacket, surmounted by a pewter still-head, having a stuffing box in its centre at top, through which works the shaft of a cross-bladed rouser, cut to the

shape of the still and actuated by a handwheel or a gut-driven wheel keyed to the shaft outside the stuffing box.

The worm should be pewter, arranged as a Liebig condenser or as an ordinary worm in a tub, the distillate being caught in a separator and afterwards strained through muslin or filter paper before storing.



PORTABLE STILLS.

Portable stills consist of complete distilling apparatus which can readily be removed *en bloc* and set to work without fixing. They are best understood as copper stills, tinned inside, fitted in wrought iron furnace frame on feet, with fire door, and ashpit

door, and smoke stack pipe. A copper globular still-head with pure tin lower end and worm in worm-tub, mounted on a wooden stand. They are used principally for experiments or distilling essences and for water distilling in small quantities. They are sometimes fitted with copper tubular rectifying heads to produce strong spirits, but the application of rectifying apparatus on such a small scale hardly warrants the expense.

In France and Italy all forms of distilling apparatus will be found mounted on wheels for removal from place to place for brandy distilling from wine lees, grape cake or fruit, where the vineyards lie far apart.

MINT STILLS.

Mint or peppermint is of two varieties, white and black. The white yields the finest oil but the black yields a larger quantity. It is grown in various parts of England: in Surrey, Sussex, Kent, Cambridgeshire, Lincolnshire and Hertfordshire; but the best comes from Mitcham, in Surrey, grown in light, chalky soil. An average crop is two tons to the acre, yielding about 10 lbs. of oil to the ton.

It is distilled in either steam or fire stills, but generally in fire stills made of copper, with copper still-heads and pewter worms in wood tubs. The distillate runs into a separator, where it is separated from the water and afterwards filtered.

A 1,200	gallon	still	will take	a charge of	1 ton	of herbs.
A 900	,,	,,	,,	,,	15 cwt.	,,
A 600	,,	,,	,,	,,	10 ,,	,,

The process is usually conducted in the most primitive, wasteful manner, the mother liquor being usually allowed to run to waste from the separator instead of being returned to the still while working or reserved for wetting the next charge; and there is no doubt a large percentage of the oil goes therefore down the drain.

ACETIC ACID STILLS.

Acetic acid is the sour principle of vinegar. Commercial acetic acid is met with under the forms of pure glacial and dilute acids, and of vinegar of many varieties. It is obtained from fermented liquors, vinegar, alcohol and wood by distillation as pyroligneous acid, and the commercial acetates of soda, potassium, lime, lead, copper, etc. The acetates acted on by strong acids liberate the acetic acid, or by distillation in vapour by heat.

Acetic acid is obtained from wood by destructive distillation, and is known as pyroligneous acid or crude acetic. It is distilled in closed iron retorts, and comes over as distillate with tar, creasote, wood spirit, and other liquids and gaseous matters, leaving charcoal as a residuum.

In this state it contains much empyreumatic matter in solution; by separation from the tar and saturation with chalk or slaked lime, defecation, and evaporation, an impure acid is obtained, which, after being gently heated, to destroy some of the empyreumatic matter without injuring the acid, it is again dissolved, defecated, and precipitated by a solution of sulphate of soda, when a solution of

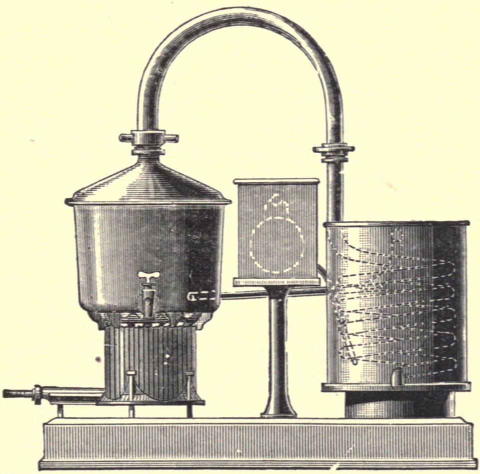
acetate of soda and a precipitate of sulphate of lime are formed by double decomposition. The solution is then evaporated to dryness and dissolved in water, then filtered and crystallized. The crystals of acetate of soda obtained yield nearly pure acetic acid by distillation with sulphuric or hydrochloric acids. One ton of oak is said to produce about 1,300 lbs. of acid and 600 lbs. of charcoal.

The cylindrical iron retorts are usually built in brickwork in sets of eight or less, with oven below for drying the acetate of lime; they vary from 2 feet 6 inches diameter to 4 feet, and from 4 to 10 feet long, and the smaller they are in diameter the more rapid the distillation. The wood is cut up and packed into the retorts as closely as possible, the average charge for each retort being about 24 cwt. One end of the retort is fitted with a hinged door, and the other end has a pipe leading away to the condensers, formed of pipes surrounded by water. The mixed distillates run from the condensers to the settling backs, which are usually made of wood. The tar falls to the bottom and is drawn off to a tar still, and the remainder is treated in various ways to produce naphtha or acid, by slow distillation to separate the naphtha either before or after the acid is neutralized by lime.

For producing pure rectified acetic acid the acetate of soda is placed in copper steam-jacketed stills covered by a stone luted on. Hydrochloric or sulphuric acid is added or fed in gradually, and the heat being applied, the vapour rises through an earthenware or pure tin still-head, and is condensed in a pure tin worm contained in a tank of water. The head is best attached to the worm by a water-seal joint

which is instantly removable, and prevents possible leakage. Stills vary in size from 50 to 300 gallons content. After distillation, the soda is dug out of the still and the still re-charged with grey or brown acetate of soda.

The copper pans of these stills should be considerably thicker than those for other purposes, and never less than $\frac{3}{8}$ inch thick, not only to resist the action of the acid, but to stand the wear and tear of the cutting they are exposed to from the edges of the shovels in digging out the soda.



THE AUTO STILL.

This apparatus was designed by the author to supply a want long felt by chemists, dispensers, wine merchants, hotel keepers, analysts, and hos-

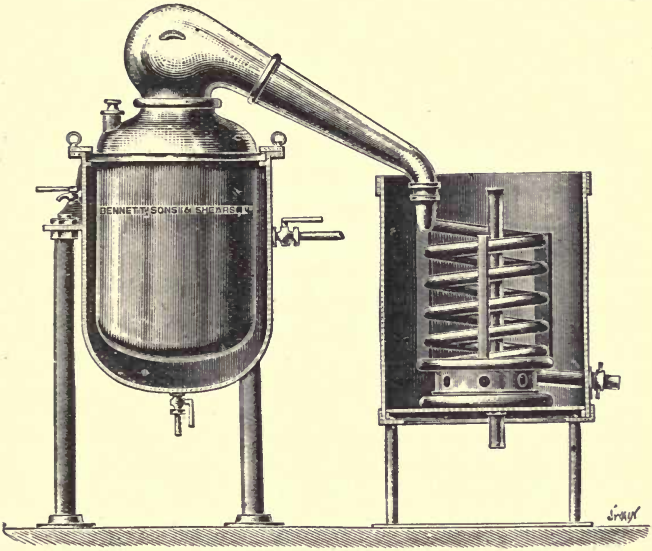
pitals, etc., *i.e.* the production of sufficient pure distilled water for their daily need, automatically, in an inexpensive apparatus, requiring no attention, at the lowest possible cost.

Even chemists who are supplied free with distilled water by wholesale houses, but have to pay for the carriage of it, will find the use of this apparatus economical.

It consists of a copper still, 2 gallons content, tinned inside and fitted with draw-off cock mounted on a low pressure atmospheric gas heater. The still is connected to a pure tin condensing worm in tank by a pure tin swan neck fitted with unions, and between the still and worm tank is a water regulating cistern, the whole being mounted on a cast-iron bedplate 2 feet long by 8½ inches wide. The apparatus simply requires connecting by india-rubber tubes to the gas and water main. The water enters the regulating cistern and passes by a pipe to the bottom of the worm tank, overflows warm from the worm tank into the still, in which it is heated and vaporized; and as each particle is condensed into distillate, so is an equally proportionate amount fed automatically into the worm-tank and thence into the still.

A gallon of boiling water may be drawn from the still without disturbing the flow of distillate. An oil lamp can be used instead of gas if required.

This apparatus produces about half a gallon of distillate per hour, or, say, 4 gallons per day.



EARTHENWARE STILLS.

Earthenware stills are used in laboratories for the production of spirits of nitre, sal volatile, prussic acid, and for rectifying ammonia, etc., and vary in capacity from 5 to 30 gallons.

The still should be provided with a thermometer passing through an india-rubber cork fitting in a tubulare on the breast of the still, and should be fitted in a cast-iron steam jacket, having its steam joint made with india-rubber rings above and below the earthenware flange, compressed into a recess cast in the jacket by a wrought-iron jointing ring with studs and gun-metal ring fly-nuts, which arrangement allows sufficient expansion, and by which,

in case of fracture, a new still can be jointed in in a few minutes. The jacket should be mounted on legs, and fitted with steam, air, and condensed water cocks and a safety valve, a guard plate being fitted inside the jacket over the steam inlet to distribute the steam and prevent it impinging directly on to one portion of the earthenware still.

The head should be luted on to the still and kept safe by a wrought-iron tripod bridle stay, which fastens on to three of the studs in the joint of the jacket; the dip arm and elbow to the worm should also have their luted joints bound or clipped together.

The worm should be contained in a galvanized iron worm tank having its outlet pipe passing through a gun-metal stuffing box and gland packed with asbestos yarn to allow of expansion, the stuffing box being bolted to the side of the tank.

The worm tank should be mounted on a convenient iron stand and be fitted with water inlet cock and copper overflow pipe, washer, and waste for cleaning it.

CARRAWAY OIL STILLS.

The best form of still for extracting oil from carraway seeds is a shallow copper still steam-jacketed at the bottom only, and mounted on columns. It should be of, say, 300 gallons capacity, with a proportionate depth to its diameter, as 1 is to 3. The bottom pan or heating surface should be shallow—say 8 inches deep,—with a flanged light course about 12 inches deep surmounting it. The

dome should be connected to this by quick releasing fastenings, and be fitted with chains and balance weights to enable it to be swung up and suspended above the still when it is necessary to discharge the spent seed.

The still should have close and free steam connections, so that either system can be used at pleasure.

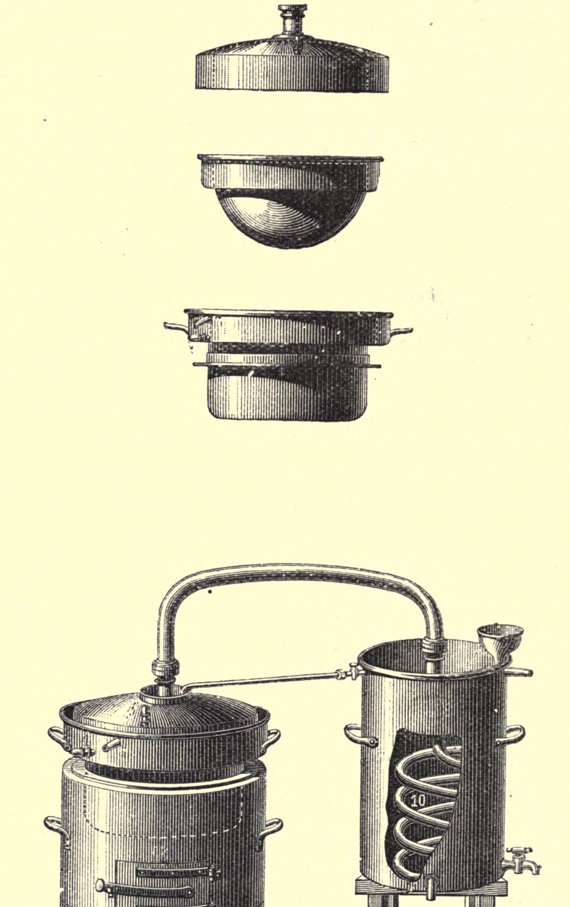
A tinned copper wire-work grating is often fitted in the still, on which the seeds are charged, and free steam blown through, carrying with it the oil into the still-head, which should be of pewter, and thence into a pewter condenser, of the Liebig type in preference, from whence it passes as distillate to the separator, where the oil is separated from the water.

As this oil is of a crystallizable nature, the condenser should be kept at a temperature of about 95° F. When close or jacket steam only is used, the still should be fitted with horizontal paddle-bladed rousers attached to a shaft working in a stuffing box fitted in the light course and actuated by gearing externally. The temperature in the still for heavy oils should not be less than 212° F., and as sometimes salt is used to retard the boiling point, it is necessary to increase the heat to 230° F.

Clove oil is distilled from cloves in a similar form of still to that described for carraway seed, but it should have a proportionate depth to its diameter, as 2 : 3.

BALNEUM STILLS.

Balneum or water bath stills are extremely useful for distilling from delicate substances which de-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teriorate under fire or steam heat, particularly when they are very thick, but they are not to be recommended for distilling or rectifying alcohol in any form, as there is a loss of aroma as compared to that distilled by a fierce heat, as well as an imperfect exhaustion of alcohol from the liquor being distilled. The balneum is a vessel which fits into a still and is surrounded by the water in the still, which, when heated, imparts its heat in a modified form to the contents of the balneum.

When it is necessary to distil alkaloid substances in pure tin, a balneum will be found very useful, as pure tin will not stand direct heat without sagging and going out of shape.

Small copper water bath stills for pharmaceutical uses, constructed so that they can be used either with or without a water bath, or as an evaporating pan in a water bath, or as an evaporating pan with direct fire or gas heat, having a removable dome fitting in a water seat round the pan, to which the still-head is attached by a union joint, cannot be over-valued in their general utility; they are in much commoner use in France than in England.

VACUUM STILLS.

A vacuum still is the greatest desideratum in a laboratory, and yet it is rarely met with. It can be used for ordinary atmospheric distillation and distillation *in vacuo*, for atmospheric concentration and concentration *in vacuo*, for drying delicate goods without change of colour in the smallest quantities

at low temperatures, and for recovering spirit rapidly from marcs without the slightest loss.

It has already been generally described under the head of vacuum pans. Where more than one distillate receiver is used the process becomes a continuous one, for as one fills, the pump suction and distillate cocks are shut off from it and those on the next receiver opened. The vacuum is then broken in the first receiver and the contents can be drawn off, after which it can be again put into use as soon as the second receiver requires discharging and a change once takes place. When concentration is taking place and the distillate is merely water, it can be run to waste; but when the distillate has any spirituous value, every particle of it can be saved.

Dry vacuum pumps can now be applied to such apparatus capable of maintaining a vacuum to within 1,000th part of a millimetre of a perfect vacuum, equivalent to the state of the barometer. Such pumps have their piston and valves perpetually sealed by suitable liquids, and are so constructed as to cause the air, instead of being drawn through the piston, to be lifted above it and discharged through the delivery valve. Thus no air can possibly return through the pump.

WATER DISTILLING.

Distilled water must not be confounded with condensed water. A very large number of manufacturing chemists content themselves with collecting the condensed water resulting from the use of steam in steam jackets, coils, etc., and not only use it them-

selves in the place of the pure article, but even sell it as *aqua destil.*, and are often prepared to argue that it is unequalled in purity.

Pure distilled water can only be condensed in pure tin worms or condensers practically free from solid matter or metallic influence, but very rarely free from ammonia; and to insure freedom from ammonia a little dilute sulphuric acid must be added to the water in the still.

The danger in using condensed water as distilled water lies in the fact that the boiler from which the steam is condensed in nearly all cases supplies some form of engine also, and consequently gets some form of impurity carried back into it, such as grease, oil lubricant or chemical matter, which is carried over again with the steam and is very difficult to eliminate.

For distilling small quantities there is no better nor efficient apparatus than the auto still already described or the simple portable still; but where a large quantity is required the apparatus must take a different form.

The still should be of copper, tinned inside and heated by a steam jacket, a steam coil, or by fire heat, and be fitted with a discharge cock, a large manhole, a vacuum valve, a set of gauge glass fittings, and a syphon charging pipe and self-regulating feed tank, so that as each drop of water is evaporated to steam it is replaced by another, and therefore the water always remains at the same level in the still. This system of feeding increases the output quite 50 per cent. per diem, and causes the apparatus to work safely without any special apparatus. Between the still-body and the still-

head should be bolted in a perforated tinned copper plate, having $\frac{1}{8}$-inch holes, $\frac{1}{4}$-inch pitch, which separate the vapour and add to its velocity, consequently increasing the output, and at the same time serving to throw down the heavy portions and thus insuring greater purity.

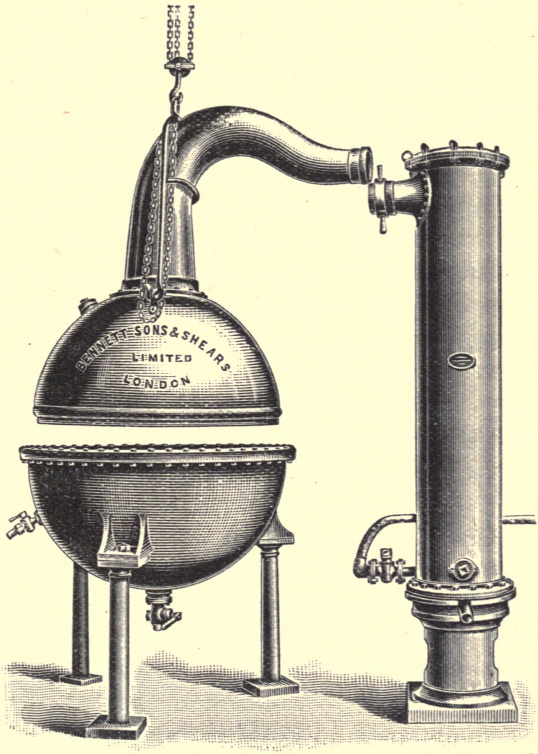
The head should be of the globular or Turk's cap form of large area to allow the vapours ample room to rotate and separate before passing to the condenser, which can be of any convenient form, but must be essentially of pure English block tin. Such stills should contain about $1\frac{1}{4}$ ft. of cooling surface to 1 ft. of heating surface, and be formed so that free access can be given to any portion of the apparatus for the purposes of cleaning.

Any ordinary portable still will produce its content in distilled water in 8 hours, and generally twice this quantity if automatically fed, as the volume of vapour is maintained continuously without any perceptible check in temperature.

CONDENSERS.

Condensing apparatus for stills is made in several forms. The common form is a circular or oblong worm of copper. Pewter or pure tin, iron, lead or earthenware are fixed in tubs or tanks, in which cold water is allowed to circulate and overflow when heated from the top.

The Liebig condenser consists of straight continuous tubes enclosed in pipe casings, and generally arranged in sets connected by semicircular bends at the ends, with a gradual fall to the outlet. They are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very convenient for fixing to a wall, and have the advantage of occupying very little space, using less water than worms in tanks and being easily arranged to command the stills, as in the case of essential oil stills, where it is necessary to return the distillate, when the oil is separated from it, back to the still while working.

The multitubular condenser consists of a number of straight tubes fixed in top and bottom tube plates, contained in an outside casing, in which as little space is left as possible, so as to obtain all the advantages of film condensation. They occupy very little space, use only half the amount of water of other forms, and are practically everlasting, as the tubes, never having been bent, are not strained and retain their true form and hardness.

The condensing water enters at the bottom and overflows at the top, and can be arranged to pass through the tubes or through the casing as desired, the casing being fitted in either case with a series of semicircular baffle plates dodged to baffle the course of the vapour or water, as the case may be, in its descension or ascension through the condenser. When the vapour goes through the tubes the condenser is fitted with a cover, which can be readily removed and allows of the tubes being brushed through or examined for cleanliness, a light being placed through the distillate pipe under the bottom tube plate.

Length of tube, or travel as it is called, is the great desideratum in the design of any condenser, and the tubes of any multitubular condenser should never be less than 5 ft. long.

SANDAL-WOOD OIL DISTILLERIES.

Sandal-wood grows in India and West Australia principally, and is very valuable on account of the oil it contains, which is largely used medicinally, and for perfuming soap, etc.

The Indian wood yields more oil and of a better quality than the Australian, but it is of a darker colour than the latter, which is nearly white. The extraction of the oil necessitates expensive plant, and requires great care and attention. The wood is first sawn into logs of suitable length, and then fed into a chipping machine, which consists of a quickly running disc fitted with knives like plane irons set at an angle. The disc is mounted on a spindle running in anti-friction bearings on a table, which spindle is fitted with a heavy flywheel and fast and loose pulleys for strap-driving. The machine having been set in motion, the logs are pressed against the cutting wheel by a sliding fence worked by a treadle, and quickly converted into chips. The chips are then fed though a disintegrator, driven at a high speed and mounted on a closed bin fitted with a dust balloon.

Then comes distillation, which is effected in a steam still of special form.

The stills are usually from 600 to 900 gallons content, and are made of copper from 6 ft. to 7 ft. 6 in. diameter, fitted in cast-iron steam jackets mounted on columns, to work at say 25 lbs. pressure of steam per square inch. They are fitted with the usual steam fittings, including a safety valve, and a very large discharge cock to discharge the spent wood.

A manhole with cover, crossbar, and screw, large enough for a man to get into easily, should be fixed on the top of the still, and a detachable U-shaped syphon pipe on to the side, through which the mother liquor is returned into the still.

A strong gunmetal cross-blade rouser should be fixed on shaft working in a stuffing box on centre of top of still, and having a toe step bearing over discharge hole at bottom, and driven by overhead revolving gearing. The bottom blade should be shaped to the bottom of still, and suspended about 1 ft. from the centre, and should be made of special acid-proof metal, and of strong form.

The vapour outlet should rise from the dome as close to the centre as possible, and be fitted with a taper copper still head 3 to 4 ft. high, surmounted by a pewter swan-neck, connected to a Liebig pewter tapering condenser in cast-iron pipe casings of large area, these casings being arranged with water inlet and outlet connections, and easy means of extracting the sludge. The whole of the condenser must command the still breast, so that the distillate can run into a separator or florentine receiver where the oil separates from the water and is skimmed off, the water or mother liquor being returned continuously to the still, through the syphon pipe before mentioned, until the distillate is quite free from oil, when it is allowed to run into a tank instead, for recharging the still.

About 5 to 8 cwt. of wood is the usual charge for a still, made up with mother liquor, which requires to be worked continuously for 3 days and nights to complete the operation.

The yield varies from 1 to 3 per cent. of oil in

weight as compared to the weight of wood charged, according to the quality of wood, and the skill of the attendant. The oil is then filtered and packed in special bottles for sale.

SEPARATORS.

Separators, or florentine receivers, are used for collecting the distillates of essential oil distillations to allow the oil to become separated from the distilled water or mother liquor, on account of the difference in density of the two bodies. They can be made of copper, pure tin, earthenware or glass, and fitted with covers and perforated straining plates, or a loose plate having a pipe attached to its centre with its end bent upwards, which hangs vertically in the separator and allows the distillate to be discharged quietly into the contents without splashing, so that accordingly as the oil is lighter or heavier than the water it ascends to the top or descends to the bottom.

The separator should be fitted with a swan-neck pipe at the side to discharge the mother liquor, having cocks to connect it to the top or bottom, so that if a light oil is collecting in the separator the bottom cock can be opened to discharge the mother liquor, and if a heavy oil the top one. Distillate containing oil has a milky appearance, which continues until it is practically exhausted of oil, so that directly it runs bright, further distillation is useless. When a sufficient quantity of oil has accumulated in the separator, it is usually drawn off by sampling cocks or skimmed off and filtered.

RECEIVERS.

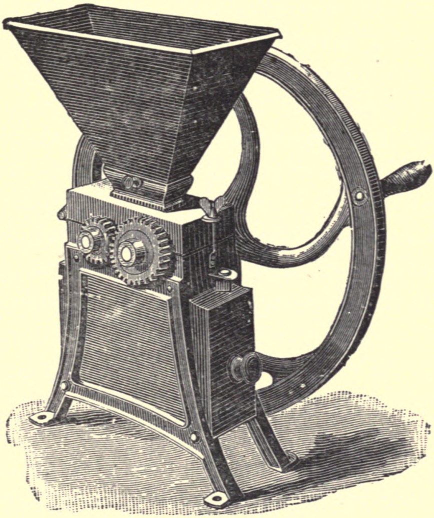
Spirit receivers should be made of copper, tinned inside and riveted together with hinged copper manhole covers at top with water seal joints, strap and padlock. They should be fitted with a vacuum and air valve combined at top, and a set of gauge glass fittings with graduated scale and suitable lock-up discharge valves. They should be oblong in form for vessels of from 100 to 500 gallons content, and circular for smaller sizes.

Open receivers can be of copper or of earthenware, and are in either case best covered with wickerwork.

DRUG MILLS.

The most generally useful form of drug-grinding mill is undoubtedly the edge runner mill, although disintegrators are now largely used for almost every form of grinding; but their product is not so evenly satisfactory as that of the edge runner mill, and in fact it is better to use a disintegrator for coarse grinding, to be finished in an edge runner mill, than to attempt to grind direct in a disintegrator to impalpable powder. Edge runner mills for drug-grinding, have stones varying from 3 ft. to 8 ft. in diameter and can be arranged so as to be driven from above or below. The stones should be made of the best granite, revolving on a granite bedstone, bedded on a concrete foundation, and surrounded by an iron curb lined with hard wood, and having an opening with sliding door and spout for emptying.

The horizontal shaft works in bushes fixed in the centre of the stones, having receptacles for oil for self-lubrication, and passes through the navel of the vertical shaft in a bush which moves up and down to suit the irregular path of the stones. The vertical shaft should be fitted with ploughs and sweepers of wrought iron, arranged for throwing in and out of gear by levers.



3 ft. edge runners will grind about 12 cwt. per day of soft drugs with 8 ft. faces on bedstone.

3 ft. 6 in. diameter			
4 „ 0 „ „	1 ton	9 faces	4 ft. 0 in.
5 „ 0 „ „	2 tons	10 „	4 „ 6 „
6 „ 0 „ „	4 „	10 „	5 „ 0 „
7 „ 0 „ „	6 „	12 „	5 „ 6 „
8 „ 0 „ „	8 „	16 „	6 „ 6 „

A very good form of finishing edge runner mill has stones 2 ft. 6 in. diameter, with 6 in. faces running say 30 revolutions per minute on a bed-stone 4 ft. diameter. This is specially suitable for finishing goods after they have been through a disintegrator. Carr's patent laboratory mill, with Minton ware pan and runner, has immense frictional power for levigating purposes and for grinding salts, etc., in small quantities. Both the pan and runner revolve, but the runner is driven at a much greater speed than the pan, and an arrangement is provided by means of which the pan can be tilted over to empty it.

The hand mill known as the universal drug mill, with helically grooved and fluted rollers, is invaluable for soft seeds, roots, herbs, etc., and is much used in France. It is provided with combs for keeping the rolls free from clogging, and is generally well suited for the everyday wants of pharmacy.

DISINTEGRATORS.

Disintegrators are largely used for grinding by percussion or by friction between two corrugated surfaces, but those working on the percussion system, although they require to be driven at higher speeds, are superior, as they actually pulverize instead of merely granulate the substance to be ground, and do not set up so much friction. The material to be ground can be fed into the machine by a self-acting arrangement, and falls on to the extremity of the beaters, and is beaten by them at a great speed and consequent force against

a series of screens lining the machine, so that it becomes pulverized to the mesh of the screen used.

They are usually made in six sizes, to crush from 3 to 30 cwt. per hour, and are driven at speeds from 5,000 to 1,000 revolutions per minute. They should be fixed on top of strong, air-tight, wooden bins, provided with dust balloons, which act as air vessels and prevent clogging.

MACERATORS.

Substances, previously either cut to pieces, incised, rasped, ground or crushed, according to their nature, are placed in water of ordinary temperature for maceration.

The proportion of water is usually 3 or 4 times the weight of the substance, and the length of time allowed for soaking is from 12 to 48 hours, according to the dryness or texture of the substance. Vessels for macerating, preparing, diluting or steeping, are made of iron, copper or wood, and are fitted with revolving rakes driven by gearing from the top, which can be worked by hand or power.

Perhaps the most useful form of macerating vessel for a laboratory is a wooden vat fitted with clip tightening hoops of metal, a perforated false bottom, and a tinned copper steam heating or boiling coil fitted underneath the false bottom, and a strainer and draw-off cock.

This can be placed overhead, so as to command the evaporating pans.

Infusions can be quickly made by drawing the liquor through a series of close vessels containing

the goods between strainer plates from one to the other by means of a vacuum, and so arranged that each vessel can be separated, and discharged or refilled at pleasure.

It is a great waste of time and space to macerate in open steam evaporating pans, as is the practice in many laboratories. It will be found much more economical to use portable copper steam jacketed percolators, which can be connected to the steam main by a flexible tube, and which can be arranged to command the pans, so that the infusions can be run off into them for concentration as soon as they are made, and the percolator recharged, so that maceration and concentration can proceed at the same time in a limited space.

DIGESTERS.

Digesters for pharmaceutical work might be much more generally and advantageously used than they are, for making extracts and infusions, for sterilizing and producing chemical reactions. Papin's digester is a close vessel with a removable cover, which can be heated over a furnace or by steam, for cooking under pressure or for sterilization, the goods to be operated upon being suspended in it in movable baskets fitted with thermometers to guide the regulation of temperature.

The more modern form of digesters consists of a jacketed vessel. Steam being admitted to the jacket at high pressure, causes exhaustion or digestion to take place in the vessel, which is fitted with a hinged screw cover, at high temperatures ensuring

rapid and thorough extraction. Bone essences and marrows can thus be entirely extracted, leaving the bone in a calcined state. Essences made in this way are placed in jars inside the digester, and lose none of their aroma or nutritious properties while cooking. Extractions from roots, herbs or barks can be readily effected, by placing them in the vessel with sufficient water to absorb the extract. Meat can easily be cooked in them by suspending it inside the vessel without adding water, its own juices being found sufficient moisture to assist in the cooking. Meat treated in this manner becomes thoroughly cooked and very tender, and by shutting off the steam from the jacket, and turning cold water in suddenly, all the gravy becomes condensed on the meat and it loses nothing in weight.

COOKING BOILERS.

Cooking boilers, for heating liquids or for making caramel, or dissolving any solid mucilaginous substances, are usually made of copper, wrought iron or galvanized iron, mounted in iron furnace frames, and arranged for tilting. They are heated by fire or gas, and are sometimes fitted with false bottoms to prevent burning. Caramel pans or boilers should be fitted with telescopic suspended hoods, to enable the vapours to be passed away into a flue. It has been found that handstirring is much more effective for caramel-making than any mechanical contrivance.

EXTRACTION OF DYE FROM WOODS.

The wood must be first reduced to powder or chips in a chipping machine or disintegrator, or sawn into small pieces, and it then goes through the process of curing or fermentation.

This consists in moistening it with water and piling it in heaps not more than 3 ft. in depth, from 4 to 6 weeks exposed to the air. It should be turned at intervals to regulate the temperature and allow contact with the air. More water should then be added, and the process continued until it assumes a rich, reddish-brown colour.

Dyewoods do not contain in their fresh condition the finished dye colours, but a chromogen capable of being converted into them by oxidisation, or by other influence—notably this is the case with logwood.

Many chemicals have been tried to hasten the process, but they are not successful, as they tend to redden the wood too quickly, and afterwards to blacken it. Glue is sometimes used to open the pores of the wood by combination with the tannin in the wood, but it is not certain that logwood contains any tannin. Curing adds, of course, largely to the bulk of the dye; few dyewoods contain as much as 10 per cent. of colour, and when chips are intended to produce extract, they usually go direct to the extractor, as oxidisation is sometimes considered objectionable. Extractors vary in form in different countries; they are often open vats with free steam injection, but in Germany and France small, closed circular "Boura" extractors are used.

They are mounted on trunnions in columns, to tilt, and are fitted with a perforated false bottom, free steam injection coil, and a discharge cock at bottom, and a manhole at top to discharge the exhausted chips when tilted over end; they are usually worked at 30 lbs. pressure per square inch.

In America a large closed type is used arranged as a battery for continuous working, and a pressure of not more than 15 to 20 lbs. per square inch is used in them. An increase of pressure produces a larger yield, but a decrease of colouring value.

The liquor is concentrated in vacuum pans to the required density, 42°–50° Twaddle = 1210–1255 specific gravity ≐ 12 to 12½ lbs. per gallon, the vacuum pans used being very similar to those used for concentrating extract of malt.

SUPERHEATED STEAM.

The use of superheated steam is very little understood generally, and rarely applied in manufacturing chemistry; but by its use immense advantages can be gained at very small cost. It enables absolutely dry steam at a constant pressure to be supplied for heating purposes at any desired temperature from 215° to 600° F., without any increase of pressure; *i.e.*, steam can be passed from a steam boiler at say 10 lbs. pressure per square inch at its normal temperature of 239° F., through a superheating coil to a close vessel, becoming raised to say 300° F. (the equivalent heat of saturated steam at 52 lbs. pressure per square inch), while its pressure remains

constant at 10 lbs. per square inch. Of course the tube surface of any superheater must be equivalent to the desired increase in temperature of the steam.

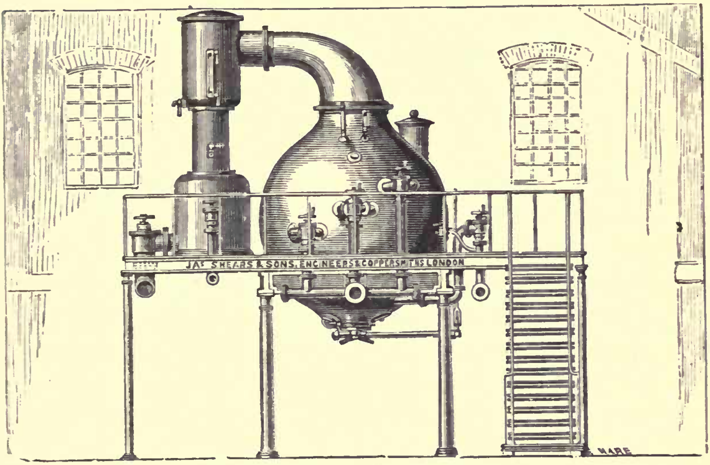
The great advantages to be derived from its use are, that as no condensation of the steam can take place, there is no obstruction by condensed water in the pipes, and the steam is therefore delivered dry, and heats the surface evenly to which it is exposed; and also that great heat can be applied economically, for the evaporation of liquids or drying of powders, etc., with steam at small pressure in vessels which are not constructed of sufficiently strong forms to withstand the necessary pressure equivalent to the same temperature if saturated steam was used instead of superheated steam.

Steam should never be heated higher than necessary, as very extreme temperatures are decidedly destructive to the packing of joints and all forms of lubricating material.

In the case of a boiler supplying steam to a steam engine, at such a distance that so much condensation takes place in the main as to decrease the pressure, if a superheating coil is placed in the brickwork flue of the boiler of correct proportions, the steam after being passed through it will enter the cylinder of the engine perfectly dry, at the same pressure and temperature as it leaves the boiler, without risk of objectionable overheating and with a distinct saving in fuel.

A very simple superheater may be formed by surrounding a vertical helical coil of hydraulic wrought-iron piping with brickwork, having its inlet and outlet pipes standing up above the brickwork, fuel, such as coke, being fed in from the top inside

and round the coil, the brickwork being open at the top and only covered with a moveable iron plate, and the ashes being raked out from a door at the bottom. In more elaborate forms the pipe is cased in cast-iron blocks, in sections connected together by external pipes, the blocks being set in suitable brickwork settings with properly constructed iron furnaces.



MALT EXTRACT PLANT.

The plant necessary for making extract of malt is practically the same as a brewing plant up to the concentration process, when a vacuum pan must be substituted for a brewing copper. The malt being landed in the factory, should be shot into a malt hopper containing the quantity to be ground for the day's work. This hopper can be of iron or of wood

lined with zinc, the bottom of which should slope not less than 12 ins. in a vertical height of 7½ ins., and have an outlet shoot feeding a revolving malt screen, which separates the stones and lumps and drops them into a bin below, also the dust, which is dropped into another bin, while the clean malt is carried through the screen into the mill. The mill should have two horizontal rolls, which can be adjusted to grind coarsely or finely, with a feed-roll above and a magnetic screen to arrest any nails or metal there may be in the malt. It should be fitted in a wooden casing, with convenient doors for examining the rolls and a removable sample tray.

The mill should either command the grist hopper or be connected to it by an elevator, or Jacob's ladder. The grist hopper can be of similar construction to the malt hopper, but should be covered and dust-tight, with large hinged doors in cover. The grist hopper should command the mash tun, and should be connected by a shoot with slides to an outside mashing machine. There are several forms of outside mashing machines for small quantities. That known as the Maitland type is the most suitable, and for large quantities a Steel's masher should be used. Their object is to perfectly mix the liquor and the grist together, so that they fall into the tun thoroughly incorporated. The mash tun, which is the most important item in the plant, can be made of cast iron, copper, or wood, preferably of English oak, with fir bottom, and should have a capacity of 108 gallons, or perhaps 144 gallons, per quarter of 336 lbs. of malt mashed, and should not be more than 4 ft. deep. It should

be fitted with the very best quality of sawn slotted false bottom plates, accurately fitted and having slots about $\frac{3}{64}$ wide by 3 in. long.

Large mash tuns should be fitted with internal rake mashing machines driven by power. The bottom of the tun should be fitted with an underlet copper main for mashing, a waste cock, and a series of special pipes and taps for running off the clear wort. The number of these pipes varies with the sizes of the tuns, but there should never be less than three. The mash tun should also be fitted with a revolving sparger of any suitable form for sparging the mash after the first wort is run off. A hot liquor tank of ample capacity for mashing and sparging should command the mash tun, fitted with a powerful steam boiling coil capable of heating its contents to boiling point in an hour. Beneath the mash tun should be fixed the underback, of about the same capacity as the mash tun, fitted with a copper steam coil to keep the first worts warm while the second are running in, or until they can be drawn into the vacuum pan, to prevent souring.

The object of the operator is to obtain all the diastase and albuminoids only from the malt, and his mash only differs from a brewer's inasmuch as the brewer's object is to obtain all he possibly can from the malt, *i.e.* to convert all the starch into maltose and dextrin by the soluble action of diastase, and this depends entirely on the heats used and the length of time of the infusion. The wort can then be pumped or drawn up by vacuum into the vacuum pan, which should be of sufficient capacity to take the whole of the first and second worts at one charge, and the charge should be concentrated right

off to the desired consistency the same day, in about four hours time.

The vacuum pan should be copper, preferably of a globular form, fitted with steam jacket and two or more copper steam boiling worms, all tinned inside, of large area through the neck and arm pipe, and be fitted with an efficient condenser, preferably of the Torricellian type, connected to a vacuum pump of sufficient capacity to keep a steady vacuum in the pan of 29 in., so that the temperature of the extract in the pan shall never exceed 130° F.

The extract, when sufficiently concentrated, can be discharged through a measuring filter into a vessel fitted with bottling valves. One quarter of malt, wetted and sparged with 216 gallons of water, should produce about 2 cwt. of extract of malt, and only the finest quality of pale malt should be used.

STEEL'S MASHING MACHINE.

The mashing machine, "Steel's Patent," was invented by a Mr. Steel, a brewer, and consists of a cylinder having an internal revolving brake driven by power. One end of the cylinder is connected to the mouth of the grist hopper, and is fitted with slides for the regulation of the grist, and directly opposite to the falling point of the grist is fixed a liquor cock. The most modern machines have two or three blades of a screw attached to the feeding end of the rake shaft to start the grist, moving forwards towards the mouth. The mouth of the machine is half covered to keep in the heat, and should have a thermometer attached to it.

Grist and hot liquor are put into the machine simultaneously, and become thoroughly incorporated by the revolving rakes, rendering mashing a simple and easily managed operation, under perfect control as to temperature desired. This machine gives excellent results, as its mash never sets, being light and buoyant, producing a high extract without loss by dusting; it occupies very little space, is easily fixed, and requires very little power to drive it. The mashing operation by the use of this machine occupies only twenty minutes with perfect blending, on account of the speed at which the rake shaft is driven.

To mash	1–3	quarters,	the machine	should	be	8½	in.	diam.
„	4–7	„	„	„	„	10	„	„
„	8–15	„	„	„	„	12½	„	„
„	16–30	„	„	„	„	15	„	„
„	30–50	„	„	„	„	17½	„	„
„	50–100	„	„	„	„	19	„	„
„	100–200	„	„	„	„	22	„	„

The machines vary in length from 3 to 8 ft., and can be used to serve two mash tuns by means of a swivelling mouthpiece.

CITRATE PANS.

Citrate pans, or steam drying tables, can be made of tinned copper, pewter, or cast iron. Copper or pewter are preferable to cast-iron, as iron is liable to rust when left out of use for any time; but if constantly in use iron is perhaps preferable, as the surface becomes oxidised, and it retains its

heat without variation of temperature better than metals of higher conductivity, on account of its thickness. They are usually about 5 ft. long, 3 ft. wide × 6 in. deep, jacketed at the bottom with a steam jacket 3 in. deep. Steam enters at one end, and is allowed to escape at the other without pressure accumulating. They should be fitted with safety valves in case of accident, and a suitable drain cock and pipe, and be mounted on a light stand to a height of 3 ft., to the top of lip of the table. About 1 cwt. per day can be made in each. Pewter tables vary in substance from $\frac{3}{8}$ in. to $\frac{5}{8}$ in. thick according to their size, and should be stayed with copper screw-collared stays and bolts burnt on to the underside of the pewter passing through the cast iron steam jacket, and fastened with nuts on washers underneath. The stays should be spaced about 12 in. pitch, centre to centre, to prevent sagging.

Copper tables can be made of slight substance, say 4 lbs. per foot super, and do not require staying, and are therefore cheaper and more generally used. They should be formed of a single sheet of copper, with sides raised up and having their corners brazed, leaving them smooth and flush inside, and having their top edge stiffened by a split brass tube, mitred at the corners and sweated on with pure metal.

EMULSIFIERS.

Emulsifiers vary in design somewhat for every kind of emulsion, and no fixed rules can be made as

to their proportions, as the ingredients often differ so much in consistency and gravity.

The most common form is the whisking machine, consisting of a closed vessel with removable cover, having a semicircular bottom, with hot water jacket below. It is fitted internally with a hollow horizontal shaft, through which works another shaft, both being revolved in opposite directions by hand gearing carried in framing attached to the outside of the vessel. To each of these shafts are attached discs carrying semicircular-shaped loops of wire, which when revolving cross-cut the mixture, and have a lifting action, causing a voluminous flow of the ingredients. In another form, the same double shaft arrangement is placed vertically and rotated by bevel wheels, straight wire with bent ends being used instead of loops, and being so arranged, that in their revolutions they pass each other closely in opposite directions, so that no portion of the goods can possibly avoid coming in contact with the stirrers.

Some of these machines are arranged so that the emulsion can be tilted out when finished, and others so that the mixing gear can be raised out of the vessel, and the vessel removed from the machine for emptying.

Malt extract and oil are readily mixed in a vessel fitted with a quick-revolving vertical shaft having a four-bladed propeller attached, which beats the oil down quickly to the bottom, causing it to rise again through the extract, the extract being previously diluted with water to reduce its gravity, and water being placed on the top of the oil to prevent air getting beaten into the emulsion. The vessel should

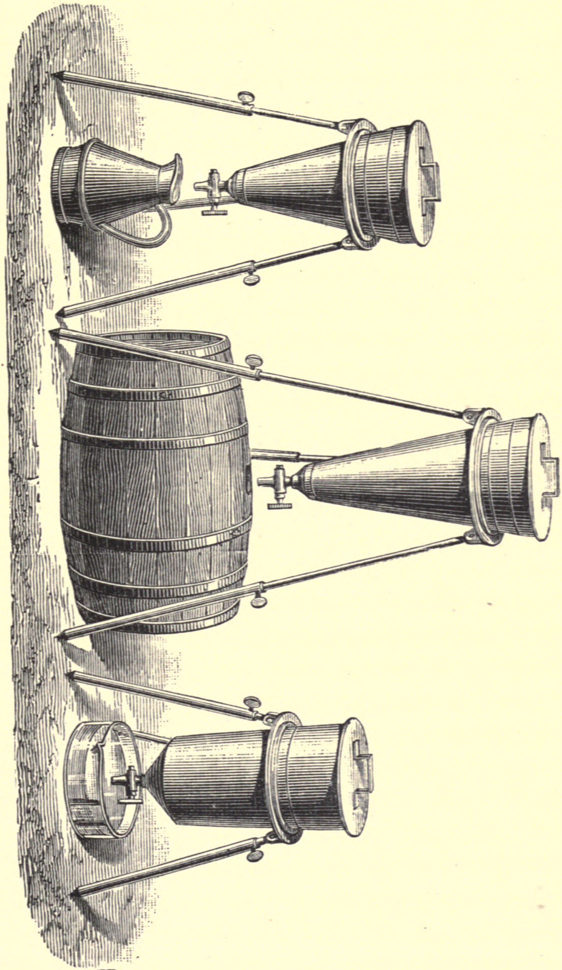
be jacketed or fitted with steam heating pipes to raise the temperature when found necessary, and should also be fitted with a run-off main and bottling valves, from which bottling can take place during the mixing operations.

PERCOLATORS.

Percolators are usually made of copper, from 1 gallon to 20 gallons capacity, tinned inside and fitted with covers and water seal joints. These joints should not be less than 3½ in. deep, to ensure an absolutely hermetical seal. They can be jacketed for steam or circulation of hot water, and mounted on trunnions if desired, but are generally supported in a stand or on a tripod frame, which can be arranged so that the legs are formed of telescopic tubes to enable it to be raised or lowered to any desired height. Percolators should be preferably in the form of a cone set at an angle of 30°, and have a discharge cock at bottom of perfect roundway bore with solid plug.

PERFUME EXTRACTORS.

The extraction of perfume from pomade is usually performed by what is known as the cold process in a form of mixing machine. It consists of a close receiver, fitted with a mechanical agitator, and having a large capscrew on its breast. The cap being removed from the screw, the spirit is placed in the receiver, and a vermicelli press is fitted on



to the screw, through which the pomade is shredded into the spirit. The press is then removed, and the cap fixed on again, and agitation is then resorted to continuously by power, or at intervals during the day by hand, until the spirit has absorbed the perfume in the pomade, when it is run off by a discharge cock at the bottom, and frozen to free it from the fat remaining in it. The cover of the receiver is then removed, and the fat scraped out and put in a still to recover the remaining spirit. This is a laborious and tedious process, lasting ten to fourteen days, resulting in serious loss of spirit. A great improvement has been made in this manufacture through the introduction by the author of a perfected apparatus known as a "Combined Extractor and Still," for extracting perfume from pomade and for recovering spirit, which performs the complete operation of two extractions and recovery in one day by what may be termed a warm process, as against at least ten days by the old or cold process. The pomade is put into the still to the level of the heating surface, spirit is then added, and the whole stirred to a perfect admixture. The jacket, having been filled with water, is heated by steam until the temperature of the mixture is equal to, but does not exceed, that of the water in the jacket, thus preventing decomposition of the fat. The valve between still and condenser being closed, and the contents properly mixed, steam is turned off, and the still allowed to cool by passing water through the jacket until the pomade sets; the spirit is then drawn off through the cock in the still body, and the still tilted if necessary. More spirit is then added, and the operation repeated. The valve be-

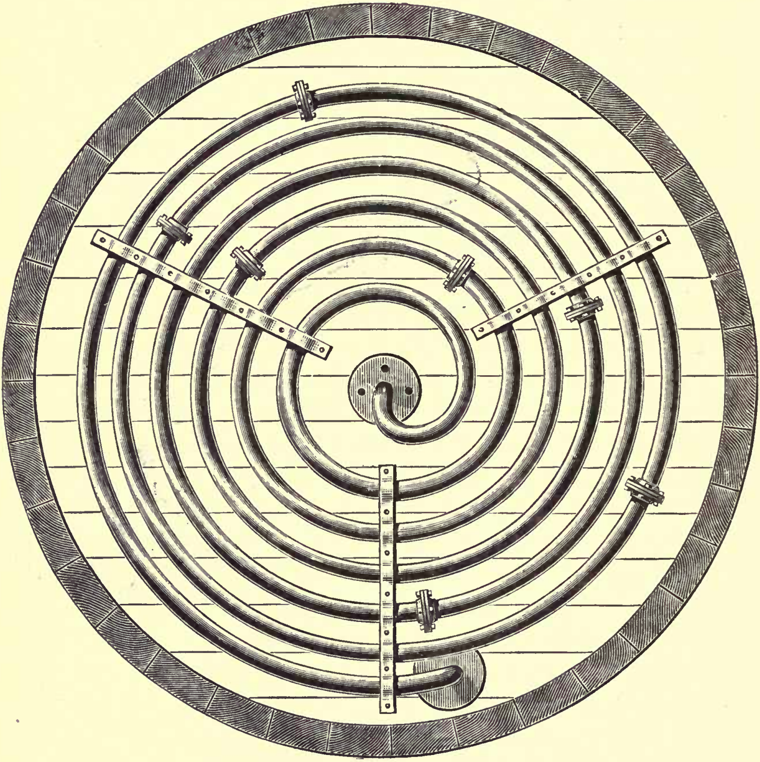
tween still and condenser is then opened, the water blown out of the jacket, and the remaining spirit is recovered by steam distillation at a high strength and used over again.

This apparatus consists of a strong copper still, tinned inside, fitted in a cast-iron jacket for use as a steam or water jacket, supported in trunnions on suitable frames with tilting gear.

It is fitted with a large capscrew, thermometer, spirit cock and funnel, steam valve, water supply cock, water escape valve, air cock, and discharge valve. The still is surmounted by a flanged copper swan-neck still-head, and lower end connected by a handled union to a valve attached to a tinned copper worm with vapour globe fitted in a galvanized iron worm tank, with copper overflow pipe, plug, washer, and waste and water inlet funnel and pipe. The still is fitted with a cross blade rouser on spindle supported on and working in a stuffing box on swan-neck and stay bar in dome of still, with disconnecting coupling and driving wheel for hand or power driving. The principal perfumes that can be extracted from pomades are cassia, jasmine, lily of the valley, orange, rose, stephanotis, tuberose, and violet. Tinctures such as ambergris, civet, musk, orris, Tonquin beans, and vanilla, etc., can be also rapidly made in this apparatus.

LIME AND LEMON JUICE CONCENTRATORS.

Both lime juice and lemon juice are now usually imported in the concentrated form and sold for citric acid manufacture on the basis of 64 oz. of



citric acid per gallon, sp. gr. 1·256. Lime juice was formerly concentrated in copper Teaches over a fire, but this is a very wasteful process, as there is a great loss by carbonization, and the juice becomes loaded with copper and of a very dark colour. Now both juices are usually concentrated by steam in oak vats, fitted with steam coils of pure block tin and with ebonite draw-off cocks. They are best arranged in tiers of comparatively shallow form commanding each other, so that the juice can be passed on from one to the other after a limited time for evaporation, and the product finished in the last one. Raw juice of 1·035 sp. gr. concentrated to 1·256 sp. gr., reduces the bulk about as 9 to 1; and this is as high as it is wise to carry the concentration.

The boiling vats vary in size from 100 to 400 gallons capacity, and are usually arranged in batteries of four. It is advisable to fit them with screw clipped hoops, so that the hoops can be tightened on them without driving them.

The steam coils should have about 1 ft. of heating surface to every 10 gallons capacity in the vat for rapid concentration, and should be made of thick pure tin pipe and lie flat on the bottom of the vats.

LIME OIL EXTRACTION.

For extracting the essential oil from the rind of lime fruit, oranges, and lemons, a peculiar form of appliance is used, known as the "Ecuelle" pan. It consists of a copper bowl varying in diameter from 12 to 9 ins. and in depth from 3 to 1½ in., studded all over inside with sharp pointed pins, and

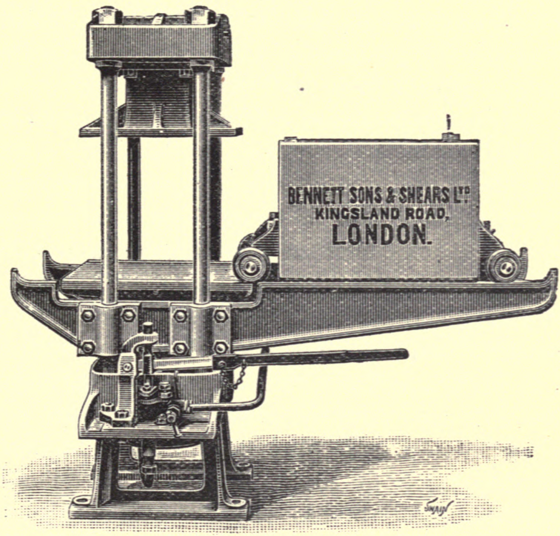
having a hollow handle like a bouquet-holder. The pitch of the pegs varies from $\frac{3}{8}$ to $\frac{3}{4}$ inches, according to the size of the fruit. The fruit is rolled round by hand on the points of the pegs, which puncture the skin, and cause the oil to exude and run down the pegs into the bowl and thence into the hollow handle, which when full is poured out into a measure. Another method is to remove the peel with a knife and collect the oil from it with a sponge or to press it out from the peel in a hydraulic press, but pressed oil contains so many impurities that its value compares very unfavourably with that collected by the Ecuelle pan, or by the sponge. It can also be separated from the juice by distillation, but the process is not a profitable one.

HYDRAULIC PRESSES.

Hydraulic presses for tincture should be thoroughly self-contained and as compact as possible, having their pump or pumps attached to work up to $2\frac{1}{2}$ tons pressure per square inch of the area of the rams and occupying as small a ground space as possible. It is most convenient in small presses to have the press box mounted on wheels arranged to run out on rails for emptying and recharging, but in large sizes, where there is plenty of room between the standard tension bars, it is perhaps better for the mullet to be arranged to run out clear of the box. Great economy can be exercised in the manufacture of these presses by keeping the rise of the ram as short as possible and dispensing with packing pieces of wood in the press box. The press box should be

ribbed down its sides and ends and fitted with a perforated lining consisting of bottom and two sides linked together to lift out, together with its loose plates and charge, whether contained in press bags or not.

A tank can be cast round the cylinder, to which the suction and delivery pipes to the pumps can be



connected, so that the same water is used over and over again. Great care should be taken in the manufacture of these presses, as the slightest fault or flaw in them is often incurable, and renders them practically useless.

A 20-ton press should have a ram $3\frac{1}{2}$ in. diameter $\times$ 6 in. rise, with box $2\frac{1}{2}$ gallons content.

A 30-ton press should have a ram 4 in. diameter × 6 in. rise, with box 8 gallons content.

A 50-ton press should have a ram 6 in. diameter × 12 in. rise, with box 16 gallons content.

ALMOND OIL PRESSES.

Hydraulic presses of special form are used for pressing the oil from almonds. They are usually of the vertical type, having 12 to 60 small plates of square or oblong form, between which the almonds are put in serge and cocoanut fibre matting cloth bags, having been previously crushed into a coarse meal. Standard guide bars are placed against the ends of these plates to keep them straight, these bars being connected to the follower and passing through slots in the press head. When the follower is raised by pressure, pumps are used for these presses to work them up to $2\frac{1}{2}$ tons pressure per square inch, and the oil on running out is caught in a channel cast round the top of the follower, with a spout from whence it runs into a press can. Presses with rams of 5 to 15 in. diameter, exerting total pressures of 50 to 400 tons, are generally used. The pressure is allowed to remain on each charge for some time until the oil ceases running, the product in oil being generally about 40 per cent. of the weight of the uncrushed almonds. The press plates should be kept as small as possible in proportion to the size of the ram, as it is essential that the pressure should only be distributed over a small surface, as a very great pressure is necessary for the work.

PUMPS.

It is always desirable to select a pump of sufficient capacity to deliver the required quantity of water at a moderate piston speed, say 60 ft. per minute. With larger pumps this speed can be increased to 75 ft. per minute, or even more. Vacuum pumps, both wet and dry, should be run from 90 to 100 ft. per minute. With thick or hot liquors the speed should be considerably reduced, according to the nature of the fluid to be dealt with and the pressure or head under which the pump is working. By choosing a pump of ample size, it is possible in case of emergency, or when a greater supply is needed, temporarily to considerably increase the piston speed, thus proportionally increasing the delivery.

Pumps are always improved by having air vessels fitted both on suction and delivery pipes to obviate air cushioning, and to more or less effectively regulate and equalize the velocity of discharge.

One foot head of water equals ·43 lbs. pressure per square inch: thus, 20 ft. = 8·6 lbs. pressure per square inch. The three-throw pump gives a more uniform discharge than any other form.

In calculating the sizes of pipes to pumps, it should be remembered that the action of a pump is intermittent, especially where there is no air vessel to regulate the velocity of supply and discharge. It is therefore advisable to have the pipes equal to about three times the area of the mean discharge.

PIPES.

The joints of cast-iron water pipes are usually made by sockets and spigots, run in with melted lead, as they admit of considerable departure from the strict straight line which is sometimes very convenient.

Flanged cast-iron pipes are not very often used for water, but are especially convenient where the joints have often to be broken.

They should always be used for steam, and should be faced right across the joints of flange. India-rubber insertion is the best jointing material for water, and asbestos or red lead and copper gauze for steam joints.

CUBIC CAPACITY.

1 imperial gallon	=277·274 cub. in.
1 " "	=0·16045 cub. ft.
1 cubic foot of sea water . . .	=64·000 lbs.
1 " inch of sea water . . .	=6·057037 lbs.
1 " foot of water . . .	=62·32 lbs.
1 " inch of water . . .	=0·036161 lb.
A cylindrical foot of water . .	=48·96 lbs.
" " inch " . .	=0·0284 lbs.
A column of water 12 in. long 1 in. square	=0·4341 lb.
A column of water 12 in. long 1 in. diameter	=0·3401 lb.
The capacity of a 12 in. cube . .	=6·232 gals.
" " " 1 in. square 1 foot long . . .	=0·0434 gals.
" " " cylinder in gallons 1 yard long .	=0·1 diameter squared.

The capacity of 1 in. diameter 1 foot long	$=0·034$ gal.
,, ,, of a cylindrical inch .	$=0·002832$ gal.
,, ,, ,, cubic inch . .	$=0·003606$ gal.
,, ,, ,, sphere 12 in. diameter . .	$=3·263$ gals.
,, ,, ,, sphere 1 in. diameter . .	$=0·00188$ gal.
1 imperial gallon	$=277·274$ cub. in.
1 ,, ,, ...	$=4·543$ litres of water.
1 litre of water	$=0·22$ imp. gals.
1 ,, ,, ...	$=61$ cub. in.
1 ,, ,, ...	$=0·0353$ cub. ft.

MEASURES.

Litres.	Imperial gallons.	Pints.
1	·22	$1\frac{3}{4}$
2	·44	$3\frac{1}{2}$
5	1·1	—
10	2·2	—
20	4·4	—
50	11	—
100	22	—
500	110	—
1000	220	—
5000	1100	—

A litre is ·22 of a gallon, *i.e.* 1 gallon = 4·54 litres. A gallon of water at 62° F. weighs 10 lbs., and contains 277·274 cubic inches or ·16046 cubic feet; hence a cubic foot of water weighs 62·321 lbs., and contains 6·2391 gallons or nearly $6\frac{1}{4}$ gallons.

The specific gravity of tallow is ·954.

$9\frac{1}{2}$ lbs. = a gallon.
59 lbs. = a cubic foot.
1 stone = 8 lbs.

THERMOMETERS.

To translate into Fahrenheit degrees the indications of a centigrade thermometer, it will suffice to multiply the number of centigrade degrees by 1·8, and add 32 to the product.

$$\text{Example: } 25^\circ \text{ C} = (25 \times 1{\cdot}8) + 32 = 77^\circ \text{ F.}$$

Inverse calculation is necessary to translate Fahrenheit into centigrade degrees.

$$\text{Thus: } 176^\circ \text{ F.} = \frac{176 - 32}{1{\cdot}8} = 80^\circ \text{ C.}$$

i.e. to convert the degrees of one scale into those of the other, a proportion must be made on the basis of the number of degrees separating the freezing and boiling points on the two scales, with the subtraction or addition, as the case may be, of the 32° advantage which the Fahrenheit scale has over the centigrade. This number is as 180 ÷ 100 or as 9 : 5.

$$\triangle\ 60 \text{ Fahrenheit } \frac{(60 - 32) \times 5}{9} = 15{\cdot}5 \text{ C.};$$

and by inverse calculations to convert 60 C.:—

$$\frac{60 \times 9}{5} + 32 = 140 \text{ Fahrenheit.}$$

To convert Réaumur scale into Fahrenheit multiply by 9 and divide by 4 and add 32.

Temperatures.

Réaumur. *Fahrenheit.* *Celsius.*

Reau.	Fahr.	Cel.	Reau.	Fahr.	Cel.	Reau.	Fahr.	Cel.	Reau.	Fahr.	Cel.
−16	−4	−20	16	68	20	48	140	60	80	212	100
−15·2	−2·2	−19	16·8	69·8	21	48·8	141·8	61	80·8	213·8	101
−14·4	−0·4	−18	17·6	71·6	22	49·6	143·6	62	81·6	215·6	102
−13·6	1·4	−17	18·4	73·4	23	50·4	145·4	63	82·4	217·4	103
−12·8	3·2	−16	19·2	75·2	24	51·2	147·2	64	83·2	219·2	104
−12	5·0	−15	20	77	25	52	149	65	84	221	105
− 1·2	6·8	−14	20·8	78·8	26	52·8	150·8	66	84·8	222·8	106
−10·4	8·6	−13	21·6	80·6	27	53·6	152·6	67	85·6	224·6	107
− 9·6	10·4	−12	22·4	82·4	28	54·4	154·4	68	86·4	226·4	108
− 8·8	12·2	−11	23·2	84·2	29	55·2	156·2	69	87·2	228·2	109
− 8	14	−10	24	86	30	56	158	70	88	230	110
− 7·2	15·8	− 9	24·8	87·8	31	56·8	159·8	71	88·8	231·8	111
− 6·4	17·6	− 8	25·6	89·6	32	57·6	161·6	72	89·6	233·6	112
− 5·6	19·4	− 7	26·4	91·4	33	58·4	163·4	73	90·4	235·4	113
− 4·8	21·2	− 6	27·2	93·2	34	59·2	165·2	74	91·2	237·2	114
− 4	23	− 5	28	95	35	60	167	75	92	239	115
− 3·2	24·8	− 4	28·8	96·8	36	60·8	168·8	76	92·8	240·8	116
− 2·4	26·6	− 3	29·6	98·6	37	61·6	170·6	77	93·6	242·6	117
− 1·6	28·4	− 2	30·4	100·4	38	62·4	172·4	78	94·4	244·4	118
− 0·8	30·2	− 1	31·2	102·2	39	63·2	174·2	79	95·2	246·2	119
0	32	0	32	104	40	64	176	80	96	248	120
0·8	33·8	1	32·8	105·8	41	64·8	177·8	81	96·8	249·8	121
1·6	35·6	2	33·6	107·6	42	65·6	179·6	82	97·6	252·6	122
2·4	37·4	3	34·4	109·4	43	66·4	181·4	83	98·4	253·4	123
3·2	39·2	4	35·2	111·2	44	67·2	183·2	84	99·2	255·2	124
4	41	5	36	113	45	68	185	85	100	257	125
4·8	42·8	6	36·8	114·8	46	68·8	186·8	86	100·8	258·8	126
5·6	44·6	7	37·6	116·6	47	69·6	188·6	87	101·6	260·6	127
6·4	46·4	8	38·4	118·4	48	70·4	190·4	88	102·4	262·2	128
7·2	48·2	9	39·2	120·2	49	71·2	192·2	89	103·2	264·2	129
8	50	10	40	122	50	72	194	90	104	266	130
8·8	51·8	11	40·8	123·8	51	72·8	195·8	91	104·8	267·8	131
9·6	53·6	12	41·6	125·6	52	73·6	197·6	92	105·6	269·6	132
10·4	55·4	13	42·4	127·4	53	74·4	199·4	93	106·4	271·4	133
11·2	57·2	14	43·2	129·2	54	75·2	201·2	94	107·2	273·2	134
12	59	15	44	131	55	76	203	95	108	275	135
12·8	60·8	16	44·8	132·8	56	76·8	204·8	96	108·8	276·8	136
13·6	62·6	17	45·6	134·6	57	77·6	206·6	97	109·6	278·6	137
14·4	64·4	18	46·4	136·4	58	78·4	208·4	98	110·4	280·4	138
15·2	66·2	19	47·2	138·2	59	79·2	210·2	99	111·2	282·2	139

The expansion of bodies by heat affords the most convenient method of measuring temperatures. Mercury is used for thermometers from 0° to 600°, and alcohol for lower temperatures, because it will not freeze; and air is used for very high temperatures, as its expansion is very regular.

In the Fahrenheit thermometer there are two standards, 32° or temperature melting ice, and 212° on the boiling point of water at atmospheric pressure, the difference between the two points, 180°, being equally divided between them, and the same measure is continued up and down the scale. The centigrade scale has the same fixed points, but they are marked 0° and 100°, and the distance between them is therefore divided by 100 points.

PILL MACHINERY.

For manufacturing pills on a small scale the first machine required is a combined kneading and mixing machine, to mix two to twelve pounds of mass at a time, which can be worked by hand or power. The mass is then passed to a piping press, consisting of a cylinder with perforated plate bottom, fitted with a plunger, having a square-threaded screwed rod, which is actuated by worm-wheel hand-gear. The mass is put into the cylinder, and forced by the plunger through the holes in the bottom plate in the form of rod or piping. The rod or piping then goes to the rotary pill-shaping and cutting machine, which can be worked by hand or treadle. It is placed horizontally between a pair of

gun-metal, grooved rollers, revolving at different speeds.

These rolls are grooved for the sized pill required, and by their rotary motion cut off the rod into pieces, and shape the pieces into pills of equal size. The pills are then placed in a pill-rounding and finishing machine, between plates with adjustable pressure, one plate having a travelling motion, and the other an eccentric motion.

Pill-coating is best performed in a copper steam-jacketed pan, with an eccentric and oscillating motion of uniform speed and motion without vibration, the powder being sifted on the pills while the pan is rotated.

When large quantities are made, the sorting and picking is performed in an automatic pill picker, which sorts out and rejects all those of defective shape, also all those which are larger or smaller than required, from those of perfect size and shape, and deposits them in boxes provided for the three different descriptions.

CONDENSED MILK.

Milk to be condensed should be drawn from the cow in the most cleanly manner, and strained into churns through wire-cloth strainers. It is then delivered to the factory, and weighed in a special tip weighing-machine. As each lot is weighed it is tipped into a receiver, which commands a vertical capillary refrigerator, over which it runs in a thin stream on the outside surface of a series of tinned

copper tubes or corrugations, and is collected in a trough at the bottom, and from whence it passes off to the scalding pan or heater. Cold water passes upwards through the inside of the tubes, entering at the bottom and having its outlet at the top, so that the coldest portion of the milk comes in contact with the coldest water, and the cooling is gradual. The milk is cooled in these refrigerators to 2° of the temperature of the ingoing water, and as the milk flows over the tubes, it is thoroughly ærated as well as cooled to about 60° F., and having a specific gravity of about 1·034, so that the two processes are completed together.

The heater or scalding pan should be of copper, of large diameter, and shallow, with bell-shaped top and straight sides, and steam-jacketed at bottom. Directly the pan is full of milk it is heated to boiling-point by steam as quickly as possible, and in some cases stirred mechanically meanwhile. It is then drawn direct into a vacuum pan, and concentrated to about 1·300 specific gravity. The vacuum pan should be of copper, half as deep again as its diameter, with steam jacket and copper boiling coils, all tinned over inside. Great care should be taken to make the pan quite smooth and flush inside, so that there be no spaces in which any secretion of particles of milk can take place. It should be fitted with efficient steaming and washing out appliances and a large manhole. None of the joints should be made with red lead cement, but they should be all tinned, then bolted together, and burnt in with pure tin, and the crevice between the joints wiped in flush with pure tin. The pan should also be fitted with an efficient tester, consisting of a

gun-metal egg-shaped measure, made in halves, with a screw in the centre, and fitted with four cocks, all made to disconnect easily for everyday cleaning. Two of the cocks have connecting pipes, one to the top of the pan and the other to the discharge plug above the discharge cock. The third is an air cock, or break vacuum cock, and the fourth is the sample discharge cock.

There should also be a large copper save-all between the neck of the pan and the condenser, with a gauge and a pipe and cock connected to the pan, so that the contents can be returned when thought desirable. This save-all catches any milk which primes over from the pan as froth, and traps it, preventing it passing through the condenser and being lost. The pan should, of course, have an efficient condenser and vacuum pump. The milk should be drawn into the pan in a thin stream, and conducted to the bottom by an internal pipe, as it froths very rapidly on meeting the change of temperature.

When sugared milk is to be made, the amount of sugar is calculated for the given quantity of milk, and it is then dissolved in a separate vessel by pouring hot milk on it. The hot sugared milk is then drawn into the vacuum pan, and mixed with the milk that is partially condensed. The sugared milk has to be concentrated more than plain milk, as the addition of sugar tends to partially liquefy the mass. Sugar is usually used in the proportion of 1¼ lb. to the gallon of milk. The milk when sufficiently condensed is let down into coolers fitted with mechanical stirrers, when it is cooled to about 70° F., then drawn into drawing cans fitted with

discharge valves, from which the tins are filled, and sealed hermetically immediately. Some makers put a drop of glycerine in each tin of sugared milk to prevent the sugar crystallizing and forming grain, as it is apt to do when it separates itself and remains at the bottom of the tin.

Under the best management and most careful examination losses will inevitably occur from time to time on account of imperfect milk, and it is evident therefore that cleanliness of the most scrupulous and comprehensive character is the first requisite in milk condensing. The milk must not only be sound, produced by healthy cows from sound and healthy food, and under generous and thoughtful treatment, but it must be kept scrupulously clean afterwards, and perfectly free from the influences of taints and ferments, and to this must be added careful watchings of the process and attention to details.

SOAP MILLING.

Toilet soaps are now almost exclusively prepared by what is known as the milling process, which originated in France. It produces toilet soap from the best and pure soap basis, highly perfumed, of uniform quality and superior finish; but although it enables much more delicate perfumes to become incorporated with the soap, yet it does not produce such a good lathering soap as the old melting and crutching process.

The crude soap basis is first cut into bars by

means of a traversing hand frame, with numerous wires set at equal distances.

The bars are then fed into a rotary cutting machine containing two discs fitted with knives set at an angle, driven by strap-power, and are cut into chips by coming into contact with the knives, and fall into a hopper below. The chips are then placed on zinc perforated trays, and stacked in a hot cupboard, heated by steam-pipes arranged at the bottom of the cupboard. The cupboard being fitted with a strap-driven fan delivering air underneath the steam-pipes, and becoming warmed, the air rises through the soap saturated with the moisture in the soap, and is drawn off at the top by an exhausting fan, and ejected.

An improved drying apparatus consists of a series of endless bands, delivering the chips from one to the other, running on drums at each end, and supported on rollers at intervals, driven by worm and worm-wheel gear off one vertical shaft, the whole being enclosed in a room over the heating pipes, and being fitted with air supply and exhaust fans. As the chips fall from the cutting machine directly on to the top band, there is great saving of labour in the use of this apparatus, but it is very costly, and has not yet come into use in England.

When the chips are dried sufficiently, they are taken to the mill and fed into the hoppers. The crushing mill consists of four granite rollers of large size, varying from 10 to 18 in. in diameter, two of which are set diagonally over the two first set horizontally. They are arranged with self-feeding

gear, and with roll-cleaning and reversible stripping scrapers.

The soap chips having been passed once through the rolls and emerging in the form of ribbon, are returned to the hopper, and the perfume and colour are then added, and the process of milling is repeated again and again, until the perfume and colour is evenly distributed and incorporated with the soap. This constant milling pressure also gives the glazed appearance which constitutes the perfection of finish.

These mills should be set perfectly level on wooden beams fixed in solid concrete beds, and be supplied with ample engine power, as the varying consistency of the soap necessitates a great variation in the power required—some days the power required being twice as great as on others.

The perfumed soap in ribbon form is then fed into a squeezing machine, or Peletouse, which consists of a taper, or in some cases, a parallel steel screw of varying pitch contained in a cylinder, which carries the soap forward, and compresses it through a die of the desired form at the mouth. There is a perforated dividing plate in front of the die, and the passage between this plate and the die is fitted with an attemperating connection. These machines, of French pattern, are usually driven by worm and worm-wheel gear, but spur-wheel gear will be found more suitable, as the speed is too great for the former function. The bars from the squeezing machines run on rollers on to a table, where they are cut off in suitable lengths for stamping. Hand-stamping machines, fitted with top and bottom dies, are mostly used, but those driven by

power, and managed by a treadle, perform more regular work, and preserve the moulds or dies in better condition.

The cakes when stamped are again dried, and stored some time before being packed for delivery.